US009475234B2

(12) **United States Patent**
Morikawa

(10) **Patent No.: US 9,475,234 B2**
(45) **Date of Patent: Oct. 25, 2016**

(54) **POWDER REMOVING APPARATUS, MOLDING SYSTEM, AND METHOD OF MANUFACTURING MOLDED OBJECT**

(75) Inventor: **Hiroaki Morikawa**, Kanagawa (JP)

(73) Assignee: **SONY CORPORATION**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 885 days.

(21) Appl. No.: **13/590,689**

(22) Filed: **Aug. 21, 2012**

(65) **Prior Publication Data**

US 2013/0052291 A1 Feb. 28, 2013

(30) **Foreign Application Priority Data**

Aug. 30, 2011 (JP) 2011-186676

(51) **Int. Cl.**
B29C 67/00 (2006.01)

(52) **U.S. Cl.**
CPC ***B29C 67/0077*** (2013.01); ***B29C 67/0096*** (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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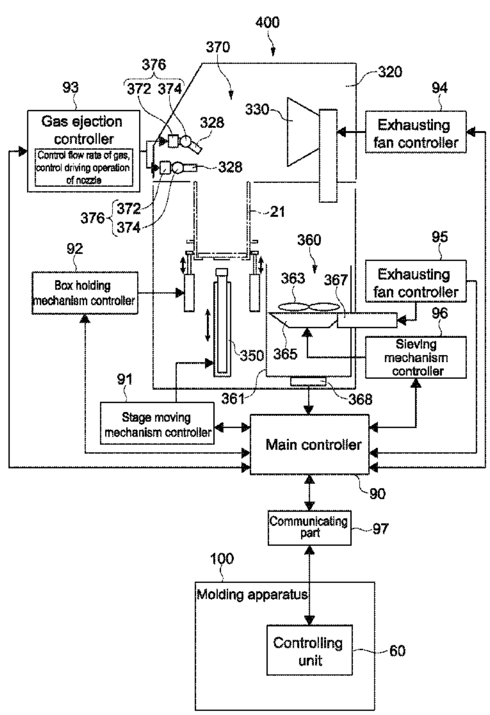
Primary Examiner — Ryan Ochylski
(74) *Attorney, Agent, or Firm* — Chip Law Group

(57) **ABSTRACT**

A powder removing apparatus includes a box, a stage moving mechanism, and a powder removing processing mechanism. The box has a main body with an opening and a stage movably provided in the main body. The box is capable of accommodating a molded object and non-bonding powder so as to arrange the molded object, which is formed using powder according to a rapid prototyping technique, on the stage together with the non-bonding powder. The stage moving mechanism is capable of moving the stage upward relative to the main body inside the main body. The powder removing processing mechanism is configured to remove the non-bonding powder existing around the molded object extruded by a driving operation of the stage moving mechanism via the opening.

12 Claims, 13 Drawing Sheets



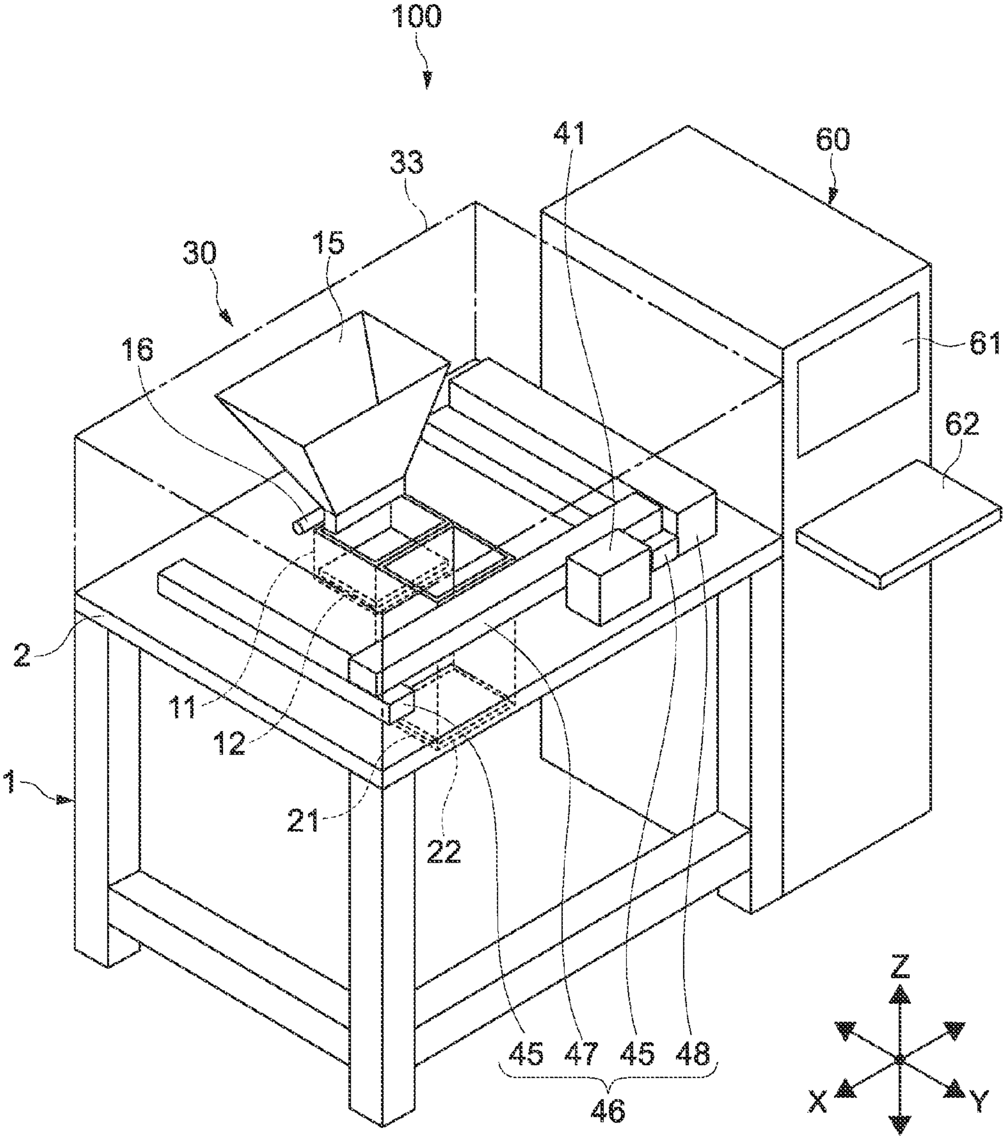


FIG.1

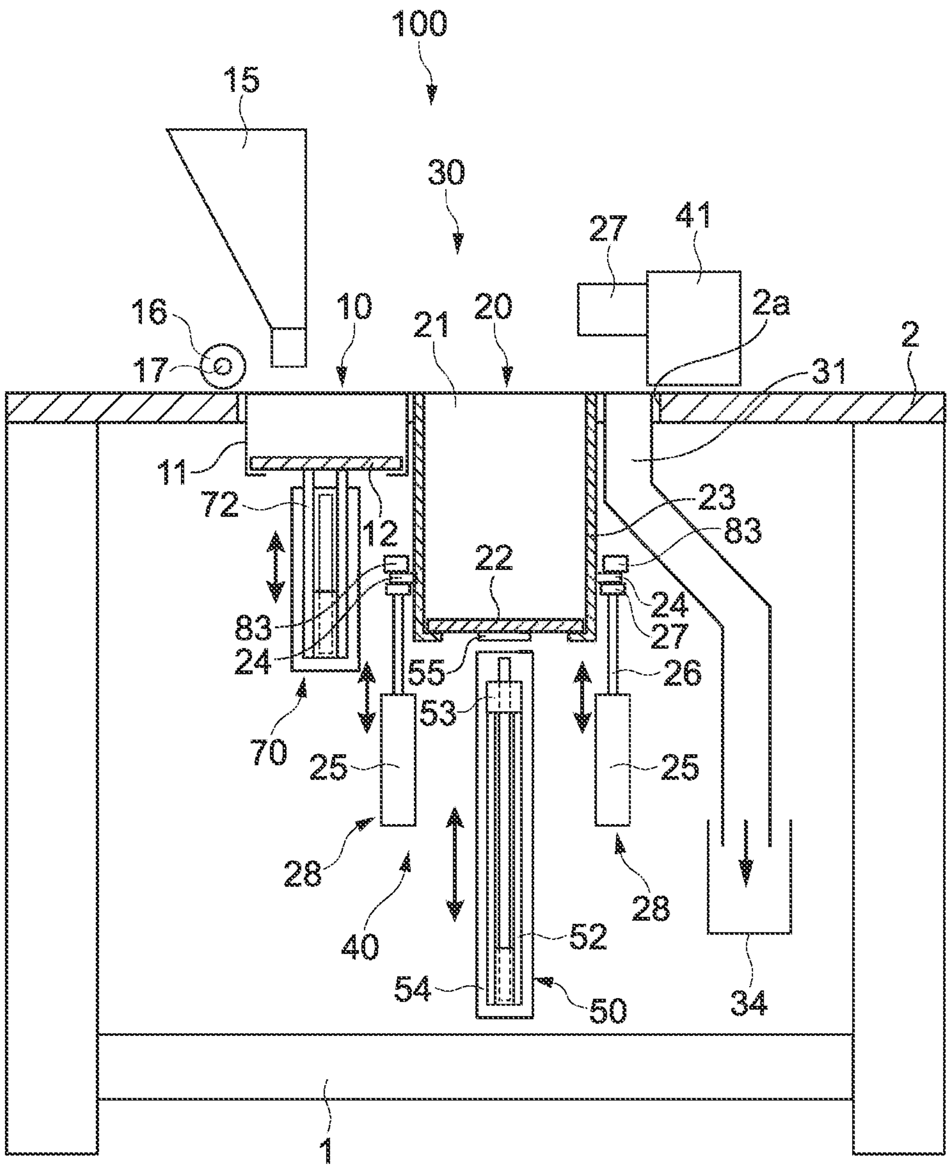
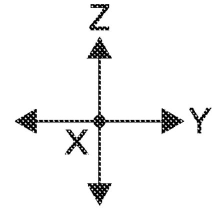

100
15
30
27
41
16
17
10
21
20
2a
2
31
11
72
12
23
83
22
83
24
24
27
55
26
53
70
25
25
28
28
40
52
54
50
34
1

FIG.2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Y
X

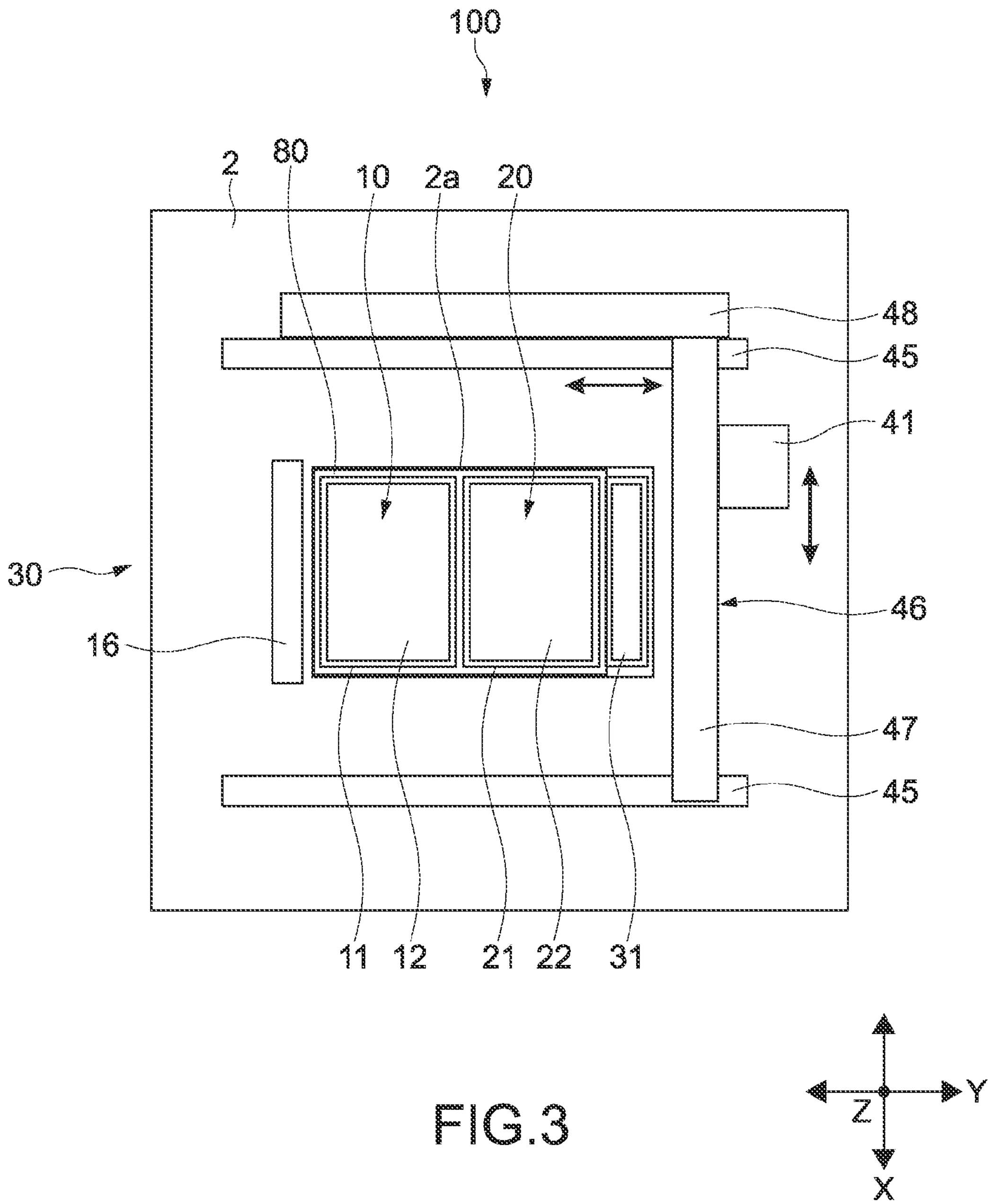


FIG.3

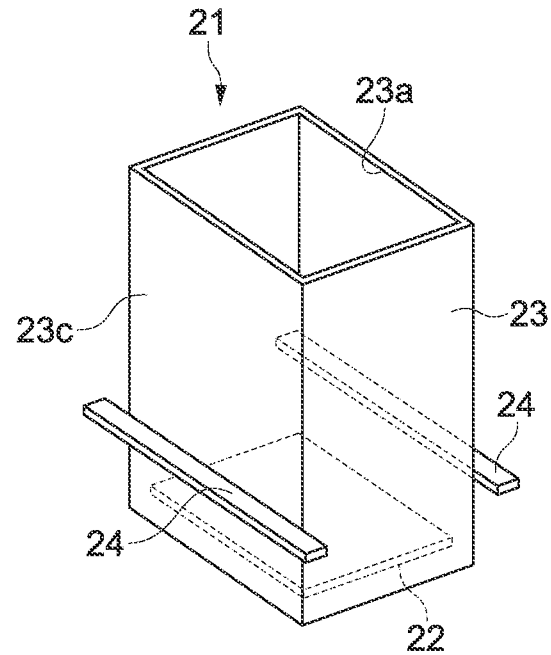


FIG.4A

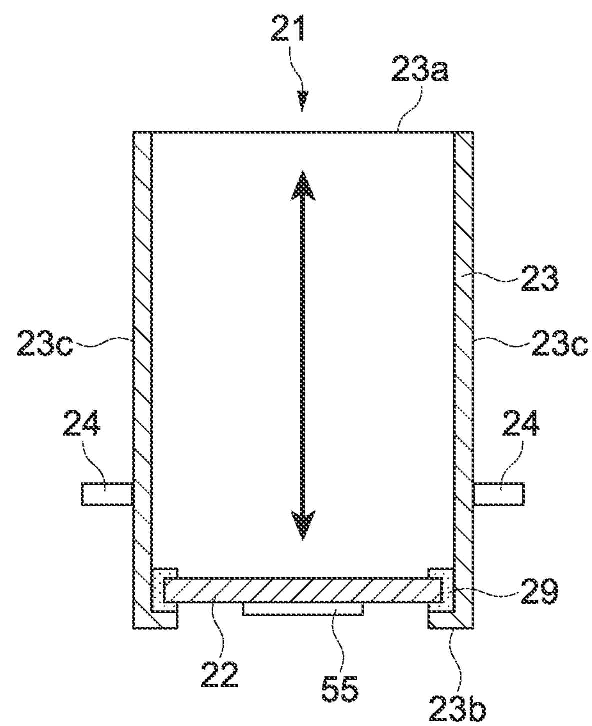


FIG.4B

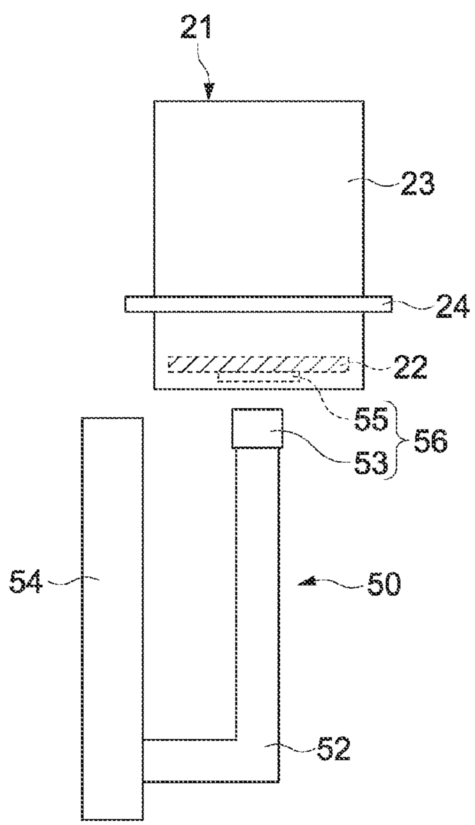


FIG.5A

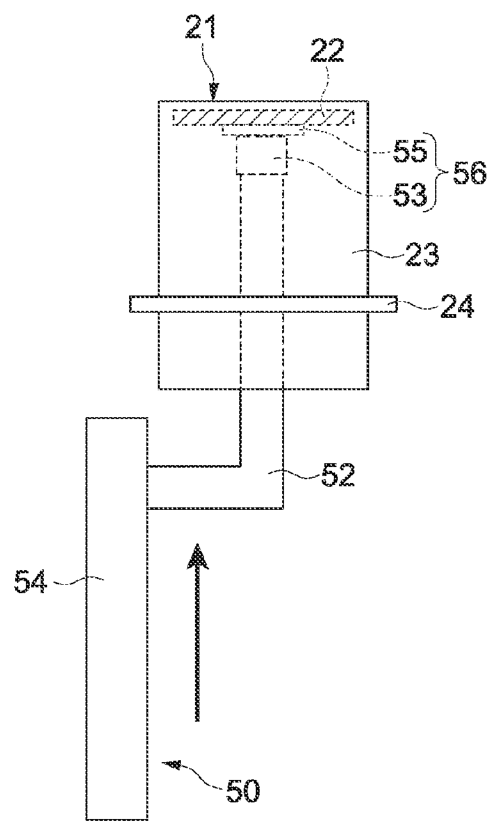


FIG.5B

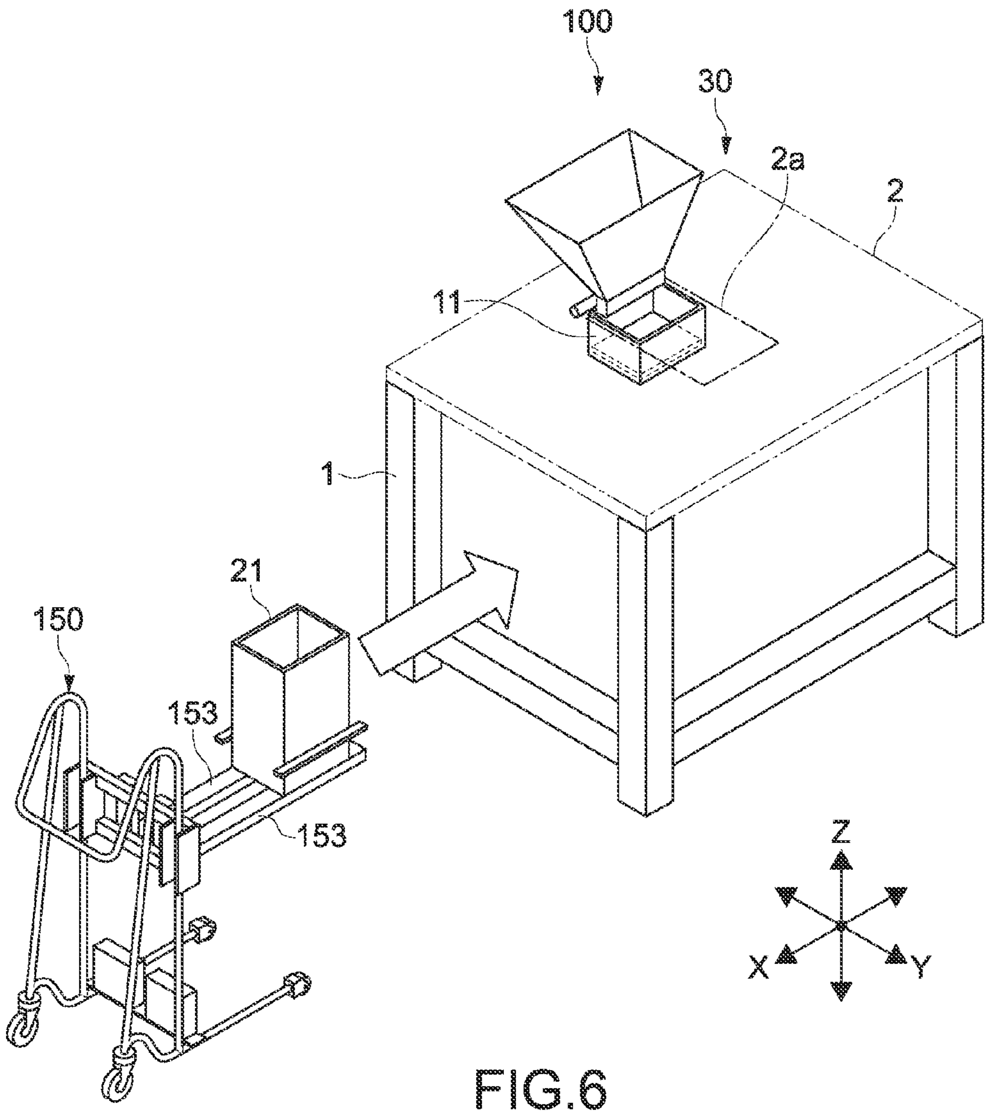


FIG.6

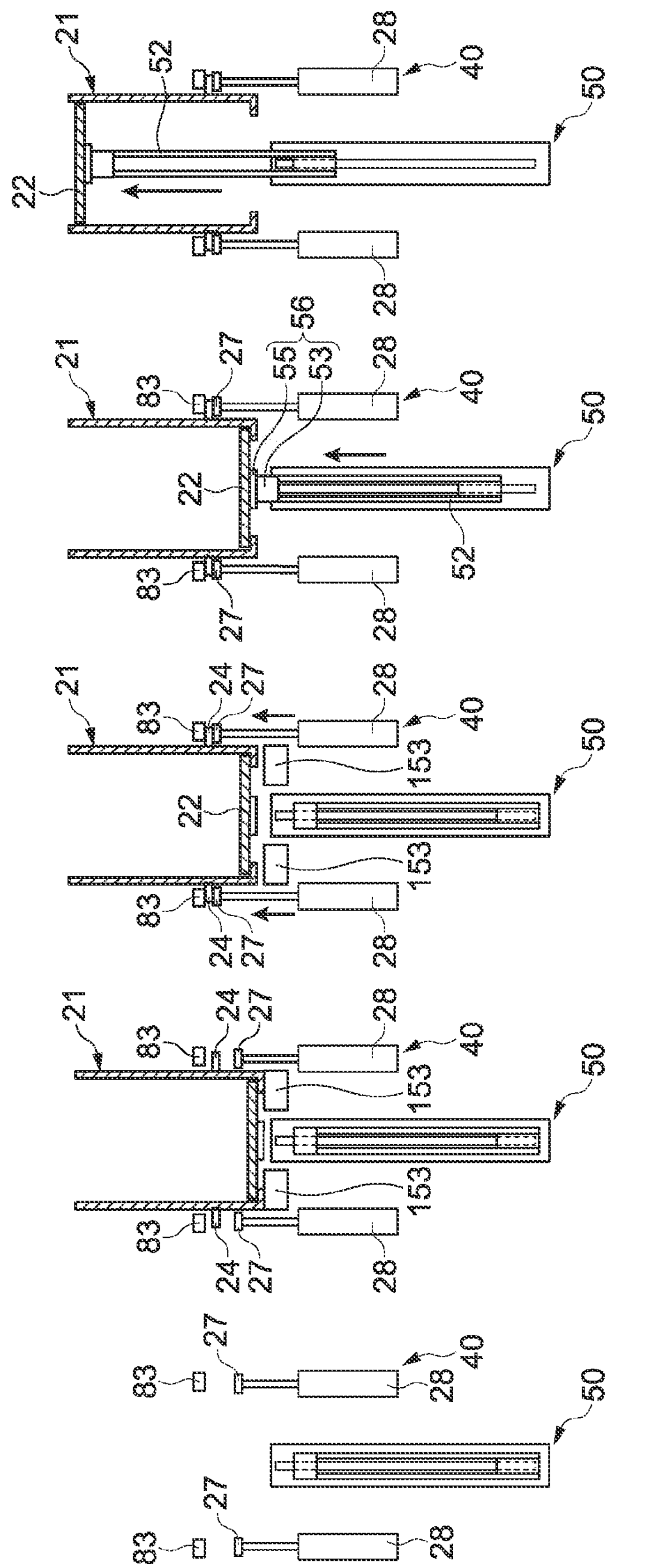


FIG.7E
FIG.7D
FIG.7C
FIG.7B
FIG.7A

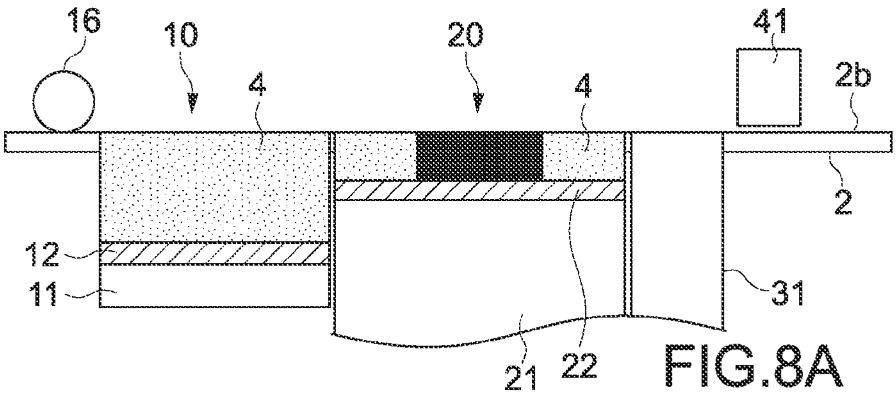


FIG.8A

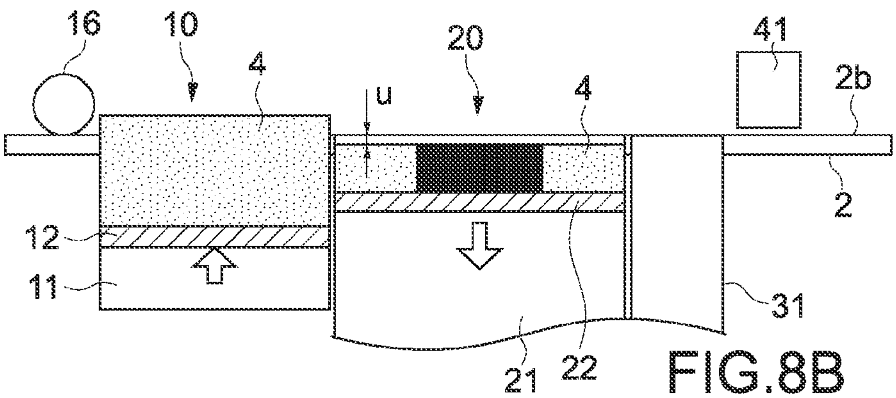


FIG.8B

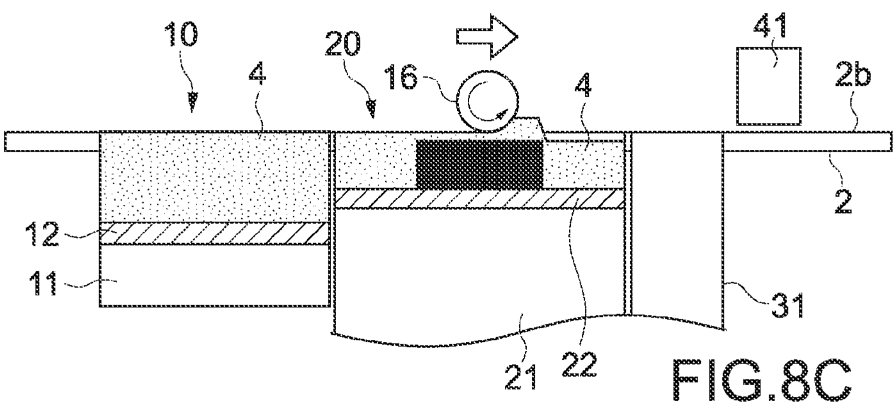


FIG.8C

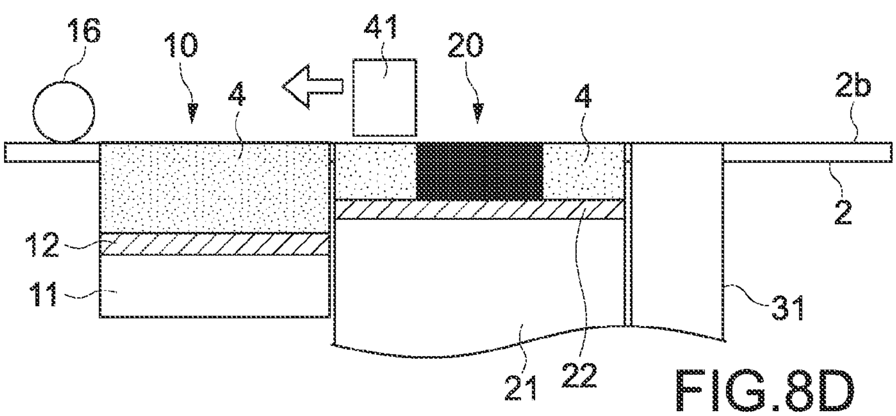


FIG.8D

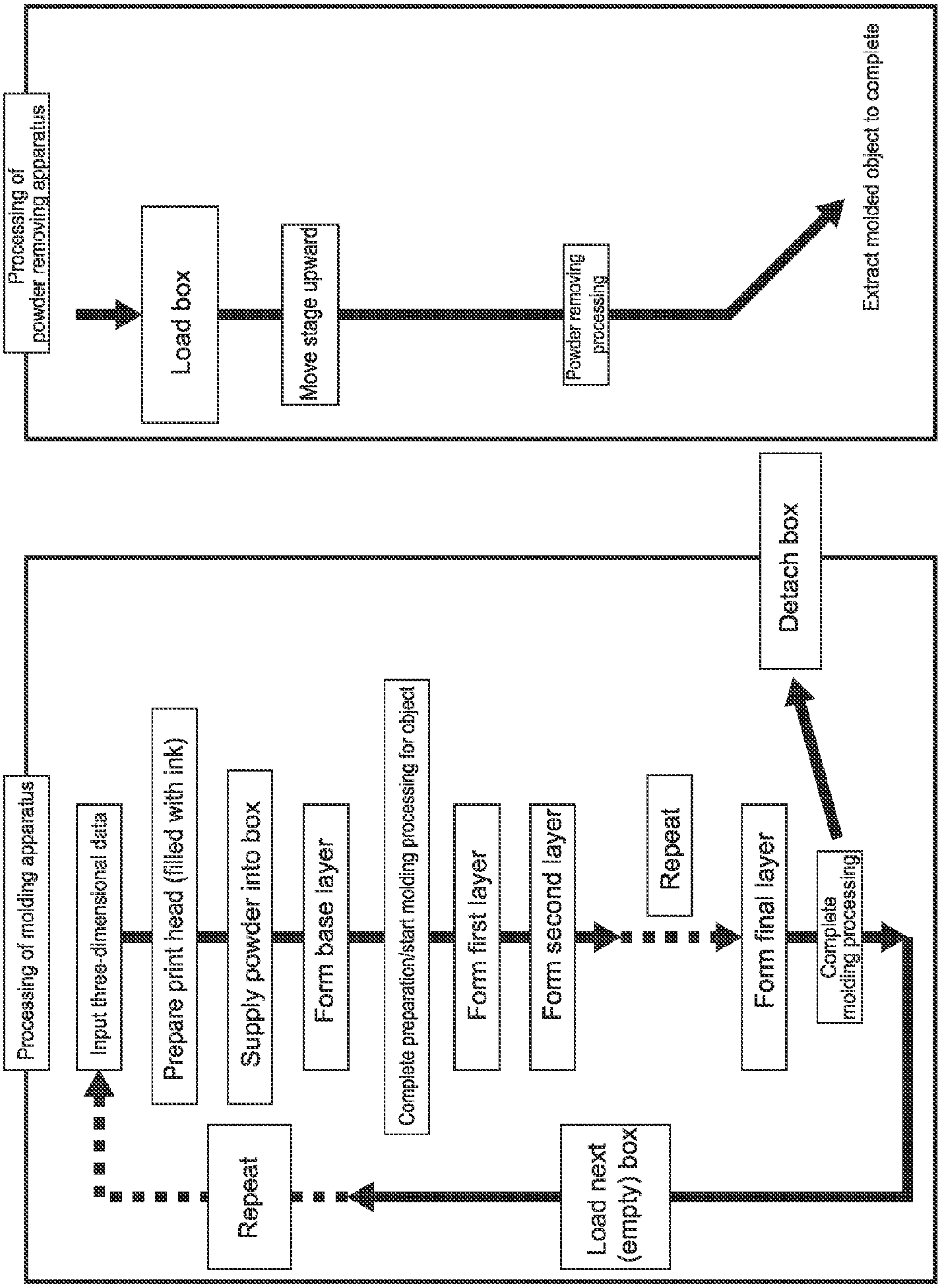

Processing of powder removing apparatus
Load box
Move stage upward
Powder removing processing
Extract molded object to complete
Detach box
Processing of molding apparatus
Input three-dimensional data
Prepare print head (filled with ink)
Supply powder into box
Form base layer
Complete preparation/start molding processing for object
Form first layer
Form second layer
Repeat
Form final layer
Complete molding processing
Load next (empty) box
Repeat

FIG.9

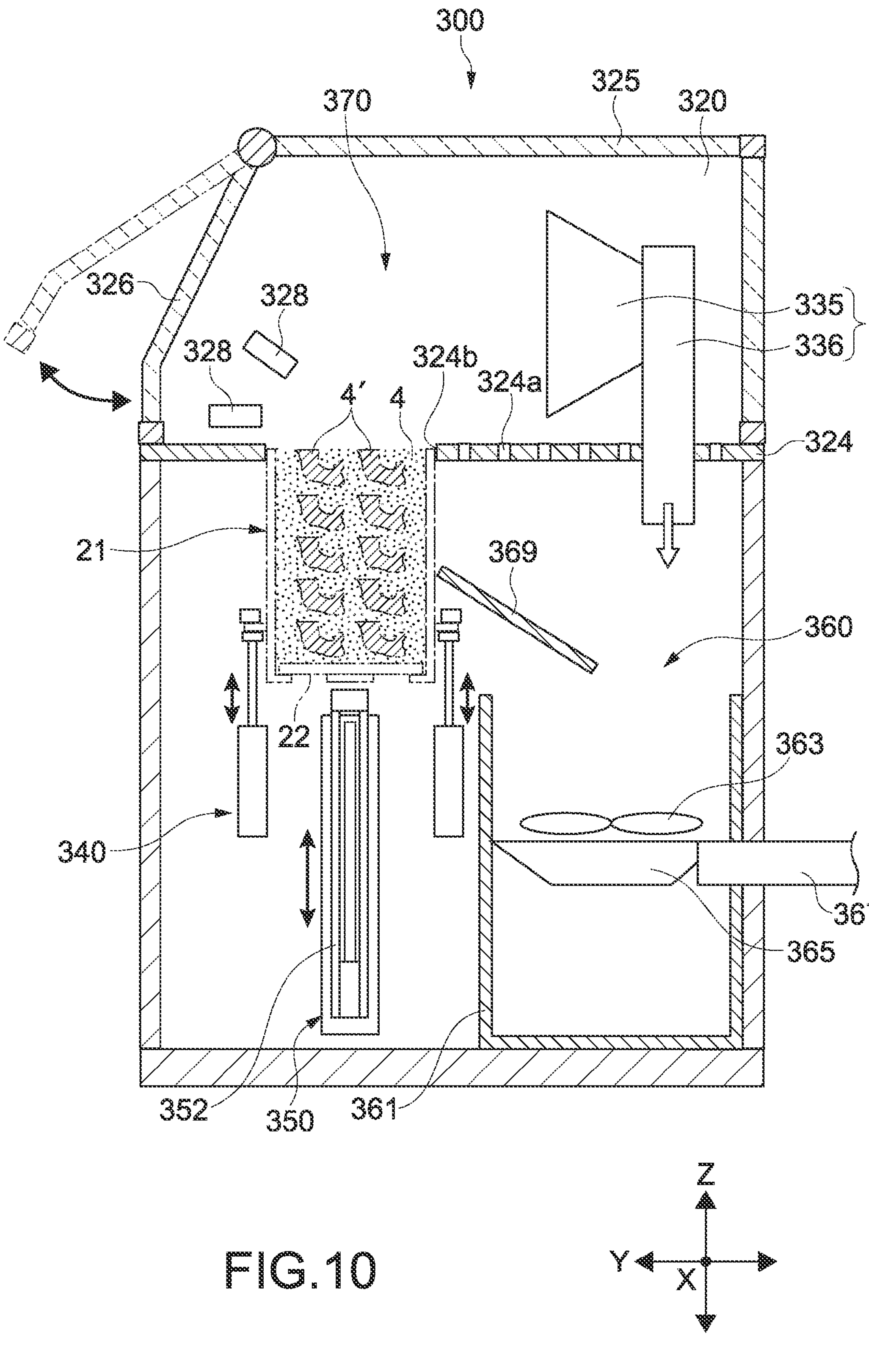
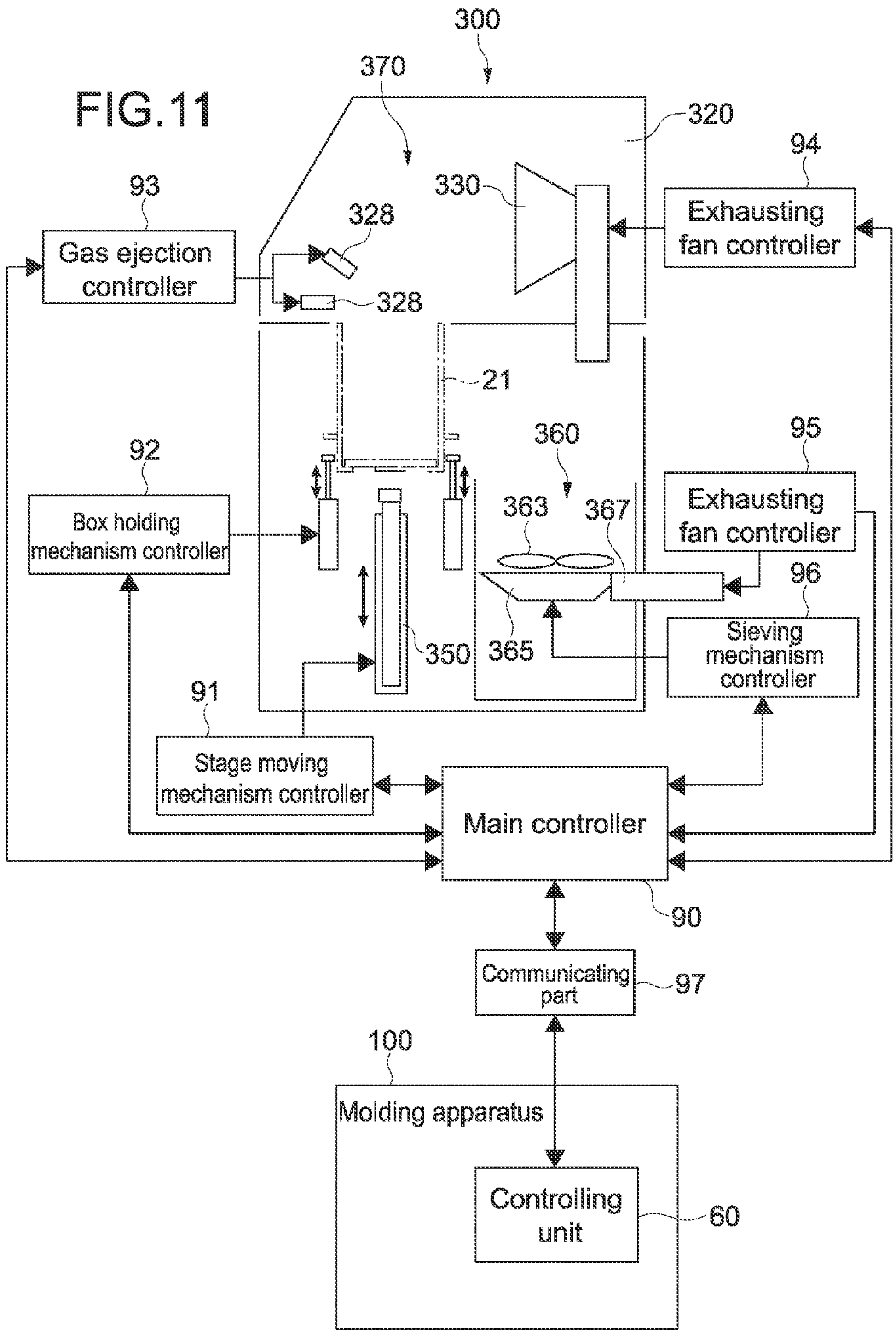

300
370
325
320
326
328
328
335
336
330
324b
324a
4'
4
324
21
369
360
22
363
340
367
365
352
350
361
Z
Y
X

FIG.10

FIG.11



300
370
320
94
Exhausting fan controller
93
Gas ejection controller
330
328
328
21
92
Box holding mechanism controller
360
95
Exhausting fan controller
363
367
96
Sieving mechanism controller
350
365
91
Stage moving mechanism controller
Main controller
90
Communicating part
97
100
Molding apparatus
Controlling unit
60

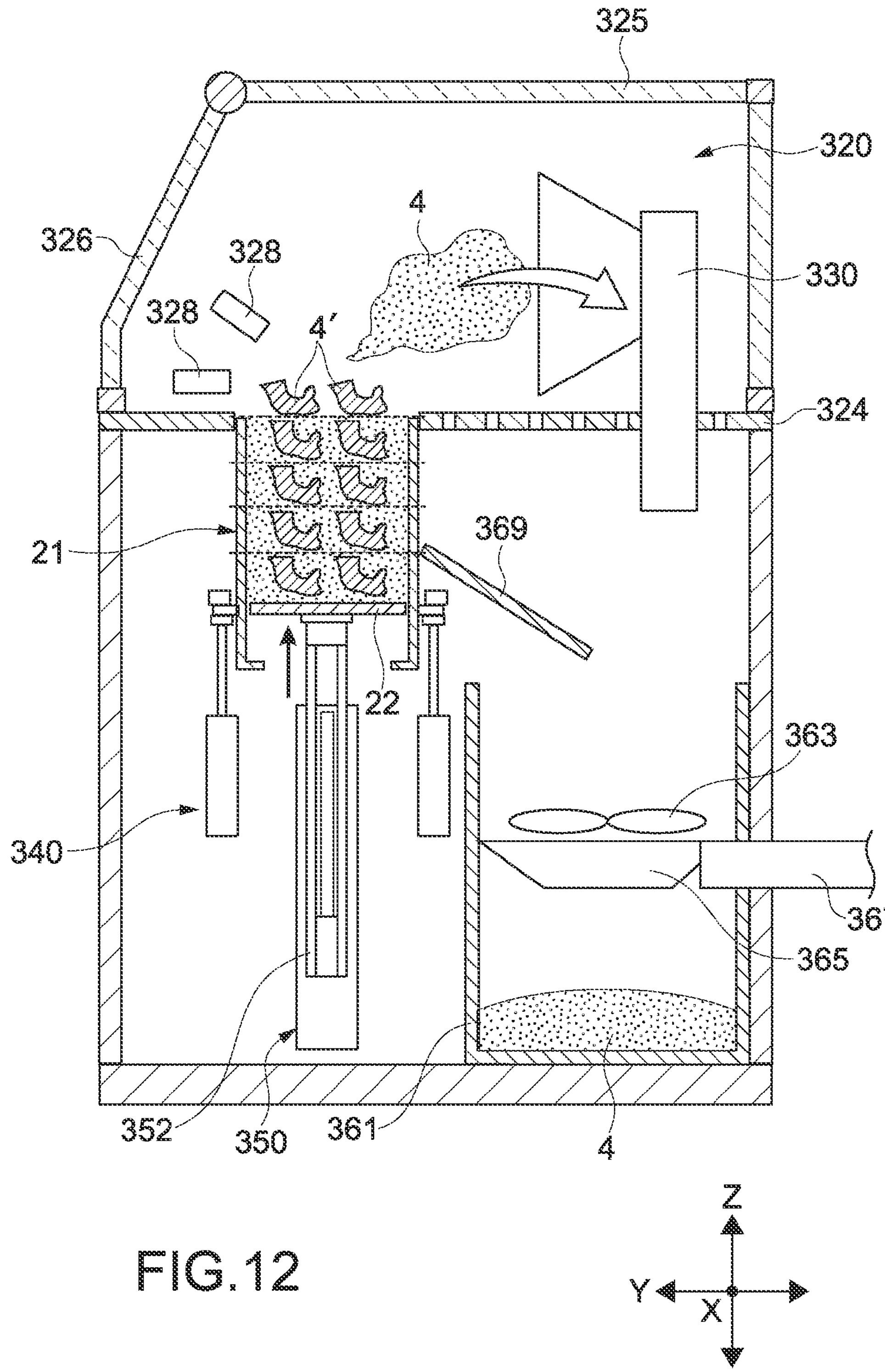

325
320
326
328
328
4
330
4′
324
21
369
22
363
340
367
365
352
350
361
4
Z
Y
X

FIG.12

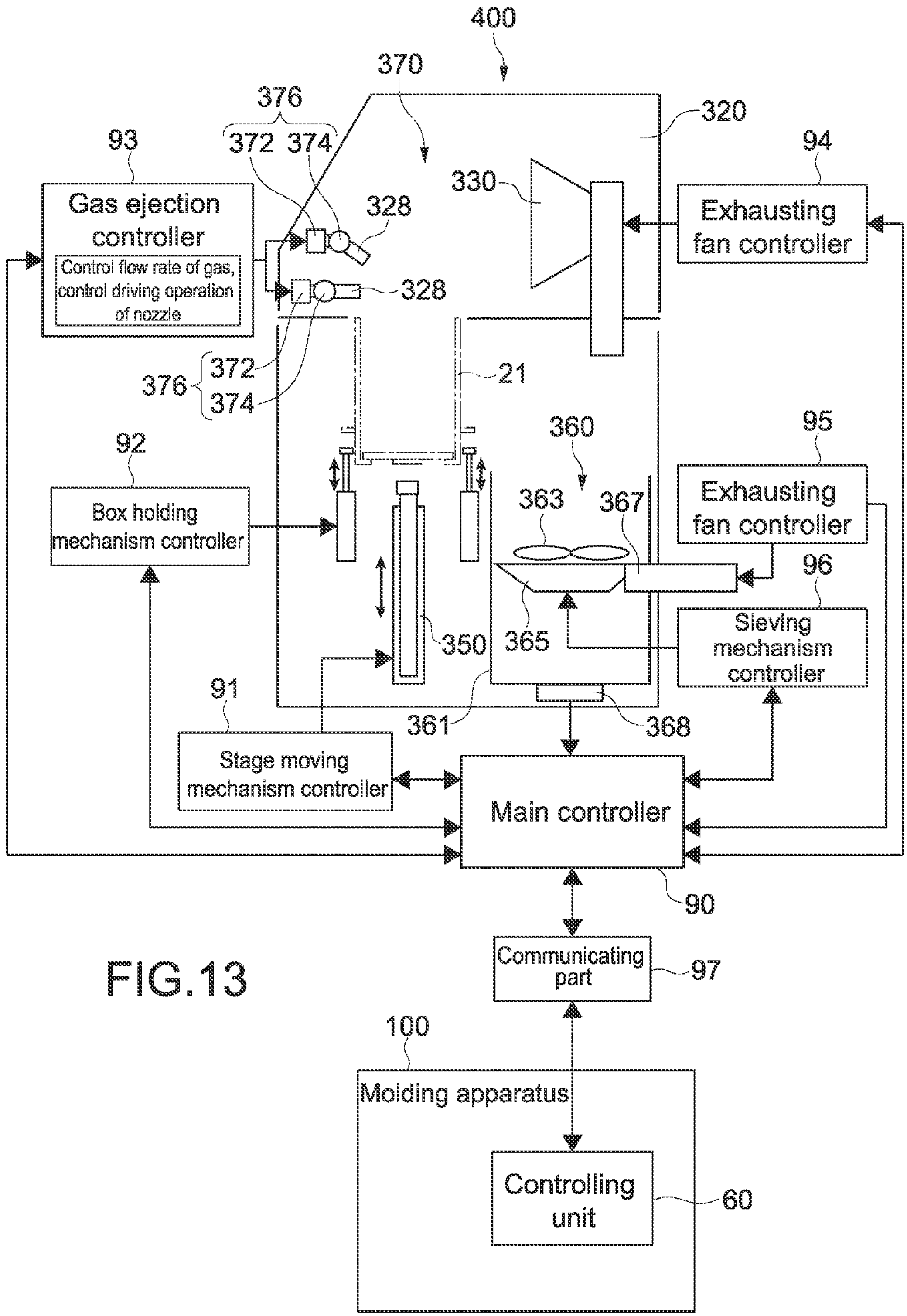

400
370
376
372 374
320
93
Gas ejection controller
Control flow rate of gas, control driving operation of nozzle
328
330
94
Exhausting fan controller
328
376
372
374
21
360
92
Box holding mechanism controller
363
367
95
Exhausting fan controller
96
Sieving mechanism controller
350
365
91
Stage moving mechanism controller
361
368
Main controller
90
Communicating part
97
100
Molding apparatus
Controlling unit
60

FIG.13

POWDER REMOVING APPARATUS, MOLDING SYSTEM, AND METHOD OF MANUFACTURING MOLDED OBJECT

BACKGROUND

The present disclosure relates to a molding apparatus that forms a molded object using a powder material according to a rapid prototyping technique, a powder removing apparatus for use in the molding apparatus, and a method of manufacturing a molded object.

A molding apparatus described in Japanese Patent Application Laid-open No. 2002-248691 has a lamination molding unit **20**, a powder removing unit **30**, and the like. In the lamination molding unit **20**, a lamination molding operation is performed to form a molded object **91** on a tray **9**. The tray **9** is moved downward by a tray conveying part **50**. After the molded object **91** is formed in the lamination molding unit **20**, the tray **9** is moved downward. Then, the molded object **91** is subjected to powder removing processing in the powder removing unit **30** (see, for example, paragraphs [0060] and [0070] and FIGS. 1, 4, and 7A and 7B of Japanese Patent Application Laid-open No. 2002-248691).

SUMMARY

As described above, it may be desired that a molding apparatus has increased efficiency of producing a product (molded object), and in particular, there may be a need for a new type of mechanism that removes a powder material.

The present disclosure has been made in view of the above circumstances, and it is therefore desirable to provide a new powder removing apparatus capable of removing powder, a molding system having the powder removing apparatus, and a method of manufacturing a molded object.

To this end, a powder removing apparatus according to an embodiment of the present disclosure includes a box, a stage moving mechanism, and a powder removing processing mechanism.

The box has a main body with an opening and a stage movably provided in the main body. The box is capable of accommodating a molded object and non-bonding powder so as to arrange the molded object, which is formed using powder according to a rapid prototyping technique, on the stage together with the non-bonding powder.

The stage moving mechanism is capable of moving the stage upward relative to the main body inside the main body.

The powder removing processing mechanism is configured to remove the non-bonding powder existing around the molded object extruded by a driving operation of the stage moving mechanism via the opening.

When the stage moving mechanism moves upward the stage provided in the box, at least part of the molded object is extruded from the opening of the main body. Thus, the new powder removing apparatus capable of removing the non-bonding powder from the upper part of the box can be provided.

The box may be capable of vertically accommodating a plurality of molded objects on a plurality of shelves. In this case, the powder removing apparatus may further include a controlling part configured to operate the stage moving mechanism such that corresponding one of the plurality of molded objects accommodated on the plurality of shelves is extruded from the main body for each of the plurality of shelves, and configured to operate the powder removing processing mechanism for each of the plurality of shelves.

According to the embodiment of the present disclosure, powder removing processing is performed for each of the plurality of shelves, and the non-bonding powder is removed from the powder removing apparatus for each of the plurality of shelves. Therefore, compared with a case, for example, where powder inside the box is discharged at one time, the random order and the random arrangement of the plurality of molded objects can be prevented. Thus, productivity for the molded objects can be increased.

The powder removing apparatus may further include an acquiring part configured to acquire related information related to the molded object inside the main body of the box and a controlling part configured to operate the powder removing processing mechanism based on the acquired related information.

The acquiring part may be configured to acquire at least three-dimensional data on the object to be molded for use in the rapid prototyping technique as the related information. For example, with the use of the three-dimensional data for forming the molded object, it is not necessary for the controlling part to generate separate information.

The powder removing processing mechanism may include a nozzle configured to eject gas onto the molded object and a nozzle driving mechanism configured to variably drive at least one of a position and a posture of the nozzle according to control of the controlling part based on the three-dimensional data. Thus, powder removing precision is increased.

The powder removing processing mechanism may include a powder removing operating region, a nozzle configured to eject gas onto the molded object, and an attracting mechanism configured to attract the non-bonding powder existing in the powder removing operating region. With the use of the nozzle that ejects the gas, the powder removing precision is increased.

The powder removing apparatus may further include a determining part configured to determine progress on powder removing processing of the powder removing processing mechanism.

The determining part may include a sensor configured to detect an amount of the non-bonding powder collected from the powder removing processing mechanism. Thus, the controlling part of the powder removing apparatus can recognize the progress on the powder removing processing based on the detected amount of the non-bonding powder.

The determining part may include a sensor configured to detect a degree of clearness of air inside a powder removing operating region of the powder removing processing mechanism. Thus, the controlling part of the powder removing apparatus can recognize the progress on the powder removing processing based on whether the air inside the powder removing operating region has a predetermined degree of clearness.

The powder removing apparatus may further include a sieving mechanism configured to remove a foreign substance from the non-bonding powder collected from the powder removing processing mechanism. Thus, the non-bonding powder from which the foreign substance is removed can be collected and recycled.

The powder removing apparatus may further include a supporting mechanism configured to detachably support the box. Thus a molding apparatus can, for example, use the box for molding processing. For example, with the preparation of a plurality of boxes, it is possible to perform the molding processing with the molding apparatus while performing the powder removing processing with the powder removing apparatus. Therefore, productivity for the molded object can be increased.

A molding system according to another embodiment of the present disclosure includes a molding apparatus that forms a molded object using powder according to a rapid prototyping technique and the powder removing apparatus described above. When the stage moving mechanism moves upward the stage provided in the box, at least part of the molded object is extruded from the opening of the main body. Thus, the molding system including the new powder removing apparatus capable of removing the non-bonding powder from the upper part of the box can be provided.

A method of manufacturing a molded object according to still another embodiment of the present disclosure includes forming the molded object using powder according to a rapid prototyping technique.

A stage is moved upward relative to a box inside a main body of the box. The box has the main body with an opening and the stage movably provided in the main body. Further, the box is capable of accommodating the molded object and non-bonding powder so as to arrange the molded object on the stage together with the non-bonding powder.

The non-bonding powder existing around the molded object, which is extruded by the upward movement of the stage via the opening of the box, is removed.

As described above, according to the embodiments of the present disclosure, it is possible to provide a new powder removing apparatus capable of removing powder.

These and other objects, features and advantages of the present disclosure will become more apparent in light of the following detailed description of best mode embodiments thereof, as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a view showing a molding apparatus according to an embodiment of the present disclosure;

FIG. **2** is a side view of the molding apparatus shown in FIG. **1**;

FIG. **3** is a plan view of the molding apparatus shown in FIG. **1**;

FIG. **4**A is a perspective view showing a box provided in a molding part;

FIG. **4**B is a cross-sectional view showing the box;

FIGS. **5**A and **5**B are schematic views for explaining an elevating mechanism;

FIG. **6** shows a state where the box is conveyed by a conveying cart;

FIGS. **7**A to **7**E are views successively showing operations where the box is loaded into a box holding mechanism;

FIGS. **8**A to **8**D are views successively showing mainly the molding operation of the molding apparatus and are schematic views as seen from the lateral surface of the molding apparatus;

FIG. **9** is a flowchart showing the processing of the molding apparatus and that of a powder removing apparatus;

FIG. **10** is a schematic cross-sectional view showing the powder removing apparatus according to a first embodiment;

FIG. **11** is a block diagram showing the configuration of the controlling system of the powder removing apparatus;

FIG. **12** is a view for explaining part of the operations of the powder removing apparatus; and

FIG. **13** is a diagram showing the schematic configuration of a powder removing apparatus according to a second embodiment and the block configuration of the controlling system thereof.

DETAILED DESCRIPTION OF EMBODIMENTS

Hereinafter, embodiments of the present disclosure will be described with reference to the drawings.

(Molding Apparatus)

(Configuration of Molding Apparatus)

FIG. **1** is a view showing a molding apparatus according to an embodiment of the present disclosure. FIG. **2** is a side view of the molding apparatus shown in FIG. **1**, and FIG. **3** is a plan view of the molding apparatus shown in FIG. **1**.

The molding apparatus **100** forms a molded object using powder as a material according to a rapid prototyping technique.

The molding apparatus **100** has a molding unit **30** and a controlling unit **60** arranged next to the molding unit **30**. The molding unit **30** has a frame **1** and a plate **2** fixed onto the frame **1**. At about a central area of the plate **2**, an opening **2***a* for use in a molding operation is provided along a Y direction, i.e., the longitudinal direction of the plate **2**. Under the opening **2***a*, a supplying part **10** that supplies powder, a molding part **20** that forms a molded object using the powder, and a discharging path member **31** (omitted in FIG. **1**) that discharges the powder are arranged. As shown in FIGS. **2** and **3**, the supplying part **10**, the molding part **20**, and the discharging path member **31** are arranged so as to be successively side by side along the Y direction from the left side of the figures.

Note that a frame (not shown) is also provided on the plate **2**, and a cover **33** is attached to the frame as shown in FIG. **1**. The cover **33** is made of an acrylic resin or the like, and a user can thus externally see the inside of the molding unit **30**. Further, the cover **33** is subjected to anti-static processing to prevent its visibility from being degraded due to the attachment of static-charged powder.

The supplying part **10** has a supplying box **11** that is capable of storing the powder **4** (see FIGS. **8**A to **8**D) and includes a supplying stage **12**, and has an elevating mechanism **70** that elevates the supplying stage **12** inside the supplying box **11**. When the elevating mechanism **70** is driven, the supplying stage **12** pushes upward the powder **4** stored in the supplying box **11** from below inside the supplying box **11** to supply the powder **4** onto the plate **2** via the opening **2***a*. As the elevating mechanism **70**, a ball screw mechanism, a rack-and-pinion mechanism, or the like is used.

As shown in FIGS. **1** and **2**, over the supplying part **10**, a tank shooter **15** that temporarily stores the powder supplied by an operator or a robot is provided. At the bottom of the tank shooter **15**, a cover (not shown) that opens and closes with, for example, electrical control is provided. When the cover opens, the stored powder falls due to its own weight and is supplied to the supplying part **10**.

As the powder **4**, an aqueous material is used. For example, an inorganic substance such as salt, magnesium sulfate, magnesium chloride, potassium chloride, and sodium chloride is used. A mixture of sodium chloride and a bittern component (such as magnesium sulfate, magnesium chloride, and potassium chloride) may be used. That is, the mixture includes sodium chloride as its main component. Alternatively, an organic substance such as polyvinyl pyrrolidone, polyvinyl alcohol, carboxymethyl cellulose, ammonium polyacrylate, sodium polyacrylate, ammonium methacrylate, sodium methacrylate, and a copolymer thereof can be used.

The powder **4** typically has an average particle diameter of 10 μm or more and 100 μm or less. Using salt as the powder **4** is environmentally friendly because energy for extraction, processing, or the like of the powder material is saved compared with a case where the powder material of metal, plastic, or the like is, for example, used.

The molding part **20** arranged next to the supplying part **10** has a box **21** capable of accommodating the powder **4** and an elevating mechanism **50** that elevates a stage **22** provided inside the box **21**. The box **21** is detachably provided in a box holding mechanism **40**. The box holding mechanism **40** and the elevating mechanism **50** will be described later.

When seen in FIG. **3**, the box **21** is set to have a length of 20 cm to 50 cm in the X direction and a length of 10 cm to 30 cm in the Y direction. However, the lengths of the box **21** are not limited within these ranges. The region where the powder accommodated in (a main body **23** of) the box **21** is arranged is used as a molding enabling region.

The supplying box **11**, the box **21**, and the discharging path member **31** have respective openings at their upper parts, and each of the opening surfaces of the openings is arranged so as to face the opening **2***a* (see FIG. **3**) of the plate **2**.

Near the end of the opening **2***a* of the plate **2** on the side of the supplying part **10**, a roller **16** that conveys the powder **4** supplied from the supplying part **10** to the molding part **20** is arranged. The roller **16** has a rotary shaft **17** (see FIG. **2**) along a direction orthogonal to the direction in which the supplying box **11**, the box **21**, and the discharging path member **31** are aligned in a horizontal plane, i.e., the X direction. A motor (not shown) that rotates the rotary shaft **17** is also provided. On the plate **2**, a mechanism (not shown) that moves the roller **16** in the Y direction is provided.

As shown in FIG. **2**, the discharging path member **31** is provided in a folded state so as not to interfere with the box holding mechanism **40**. Under the discharging path member **31**, a collecting box **34** is arranged. The excessive powder falling via the discharging path member **31** due to its own weight is collected into the collecting box **34**.

Over the plate **2**, a print head **41** and a print head moving mechanism **46** that moves the print head **41** in the X and Y directions are provided. The print head **41** is capable of ejecting ink onto the powder **4** stuck on the stage **22** in the molding part **20**. The print head **41** and the print head moving mechanism **46** serve as a supplying mechanism that supplies a liquid.

The print head moving mechanism **46** has guide rails **45** extending along the Y direction on both sides in the X direction of the opening **2***a*, a Y axis driving mechanism **48** provided at the end of one of the guide rails **45**, and an X axis driving mechanism **47** bridged between the guide rails **45**. The print head **41** is connected to the X axis driving mechanism **47** so as to be capable of moving in the X direction. Further, with the Y axis driving mechanism **48**, the X axis driving mechanism **47** is capable of moving in the Y direction along the guide rails **45**. The X axis driving mechanism **47** and the Y axis driving mechanism **48** are composed of a ball screw mechanism, a belt mechanism, a rack-and-pinion mechanism, or the like.

As the print head **41**, one having the structure of a known ink jet print head may be used. For example, inside the print head **41**, a plurality of ink tanks (not shown) are provided. The ink tanks store the colors of ink, cyan, magenta, and yellow, respectively (hereinafter referred to as CMY).

Although not shown in the figures, a tank that stores, for example, transparent ink is also provided inside the print head **41**. The transparent ink includes a binder for bonding and curing the powder as its component. As the binder, polyvinyl alcohol is typically used. However, the binder is not limited to polyvinyl alcohol.

As the ink, aqueous ink is, for example, used. Further, it is also possible to use ink for commercially available ink jet printers. The ink may be oily depending on the material of the powder **4**.

As the system of the print head **41**, a system different from an ink jet system may be employed.

The controlling unit **60** has functions as a computer including a CPU, a RAM, and a ROM. In addition, the controlling unit **60** has a display part **61** arranged at the upper area of its front surface and input operations equipment **62** arranged below the display part **61**. The input operations equipment **62** is typically composed of a keyboard. The display part **61** may have an input device with a touch panel.

To the controlling unit **60**, CT (Computed Tomography) data is input. Based on the input CT data or three-dimensional data obtained according to the CT data, the controlling unit **60** controls the operations of the respective parts of the molding unit **30** and the timings thereof to form a molded object.

FIG. **4**A is a perspective view showing the box **21** provided in the molding part **20**. FIG. **4**B is a cross-sectional view showing the box **21**.

As described above, the box **21** includes the main body **23** having the opening **23***a* at its upper end and the stage **22** that is movably provided in the main body **23** and constitutes the bottom plate of the main body **23**. The main body **23** is formed into a square cylinder, and the stage **22** is formed into a square plate so as to match the shape of the inner surface of the main body **23**. As shown in FIG. **4**B, a flange part **23***b* is provided at the lower area of the main body **23**. The volume of the main body **23** becomes the greatest when the periphery of the stage **22** is mounted on the flange part **23***b*.

A sealing member **29** is attached to the periphery of the stage **22** and seals the gap between the main body **23** and the stage **22**. The sealing member **29** is made of a sponge-like material such as urethane. At the rear surface of the stage **22**, a permanent magnet **55** is, for example, attached as a member constituting part of a clamping mechanism **56** that will be described below. Note that the sealing member **29** is omitted in FIG. **2**, FIGS. **7**A to **7**E, and the like.

At lateral surfaces **23***c* of the main body **23** of the box **21**, supported members **24** supported by supporting members **27** (that will be described later) of the box holding mechanism **40** are provided. The supported members **24** are formed into, but not limited to, plates. The supported members **24** may only be provided at least at part of the periphery of the main body **23** in a continuous or intermittent state such that the supporting members **27** of the box holding mechanism **40** can support the box **21**. According to the embodiment, the supported members **24** are provided at the pair of opposing lateral surfaces **23***c* of the main body **23**.

As shown in FIG. **2**, the box holding mechanism **40** has a pair of elevating cylinders **28** and a pair of stoppers **83**. The elevating cylinders **28** and the stoppers **83** are attached and fixed to an attachment frame (not shown) provided in the molding unit **30**.

The elevating cylinders **28** have respective driving parts **25** and rods **26** elevated and moved by the driving parts **25**, and the tip ends of the rods **26** are attached to the supporting members **27**. That is, the supporting members **27** support the supported members **24** provided at the box **21** from below. As the elevating cylinders **28**, fluid pressure cylinders (typically air cylinders) are, for example, used. The driving operation of the pair of elevating cylinders **28** is controlled by a controller (not shown) of the molding unit **30** or the controlling unit **60** such that the elevating cylinders **28** are driven in synchronization with each other.

The pair of stoppers **83** has the function of restricting the upward movement of the supporting members **27** when the elevating cylinders **28** move the supporting members **27** upward. When the supported members **24** come in contact with the stoppers **83**, the box **21** is positioned at the molding part **20**.

FIGS. **5**A and **5**B are schematic views for explaining the elevating mechanism **50**.

The elevating mechanism **50** has a driving part **54**, an elevating arm (elevating member) **52** elevated and moved by the driving part **54**, and the clamping mechanism **56** where the elevating arm **52** clamps the stage **22**. The elevating arm **52** is formed into, for example, an L-shape.

For example, the clamping mechanism **56** has a magnetic field generating device **53** attached to the upper end of the elevating arm **52** and has the permanent magnet **55** at the rear surface of the stage **22** as described above. The magnetic field generating device **53** generates a magnetic force with the energization of a coil (not shown), and the magnetic force acts on the permanent magnet **55** to connect the magnetic field generating device and the permanent magnet **55** together to clamp the stage **22**. In FIG. **5**B, the clamping mechanism **56** operates to clamp the elevating arm **52** to the stage **22**, and the elevating arm **52** pushes the stage **22** upward.

The elevating mechanism **70** of the supplying part **10** has basically the same structure as the elevating mechanism **50** but is different from the elevating mechanism **50** in that the supplying stage **12** is directly attached to the end of an elevating arm **72**.

FIG. **6** shows a state where the box **21** is conveyed by a conveying cart. The conveying cart **150** has forks **153** that hold the box **21**. When an operator moves the conveying cart **150** and places the forks **153** into the molding unit **30**, the box **21** is arranged at a predetermined position.

(Operations Prior to Molding Processing of Molding Apparatus)

FIGS. **7**A to **7**E are views successively showing operations where the box **21** is loaded into the box holding mechanism **40**.

First, the mechanisms of the respective parts of the molding apparatus **100** are set at their original positions (initial positions). The original position of the box holding mechanism **40** is set at the position as shown in FIG. **7**A. That is, at the original position, the supporting members **27** of the elevating cylinders **28** are set at positions lower than those shown in FIG. **2**.

As shown in FIG. **6**, an operator moves the conveying cart **150** so as to place the forks **153** of the conveying cart **150** into the molding apparatus **100**. Then, as shown in FIG. **7**B, when the operator operates the molding apparatus **100** via the input operations equipment **62**, the box holding mechanism **40** starts holding the box **21**.

As shown in FIG. **7**C, in the box holding mechanism **40**, the supporting members **27** move upward with the driving operation of the elevating cylinders **28**. When the supporting members **27** move upward while being in contact with the supported members **24**, the box **21** is lifted and comes off from the forks **153**. The elevating cylinders **28** move the supporting members **27** upward until the supported members **24** come in contact with the stoppers **83**. When the supported members **24** come in contact with the stoppers **83**, the upward movement of the supporting members **27** is completed. In this manner, the box holding mechanism **40** holds the box **21**.

Because the elevating mechanism **50** is arranged under the box **21**, the box holding mechanism **40** holding the box **21** has a very simple configuration with such a less movement.

The operator reversely moves the conveying cart **150** to pull out the forks **153** from the molding apparatus **100**. The operator may pull out the forks **153** after slightly moving the forks **153** downward for safety.

Next, as shown in FIG. **7**D, the elevating mechanism **50** starts operating. The elevating arm **52** moves upward, and the clamping mechanism **56** clamps the stage **22**. After the stage **22** is clamped, the elevating mechanism **50** moves the stage **22** upward to the uppermost position of the main body **23** of the box **21**, i.e., the position near the opening of the main body **23** as shown in FIG. **7**E. Then, molding processing (see FIGS. **8**A to **8**D) that will be described below is started.

According to the embodiment, the box holding mechanism **40** detachably holds the box **21** as described above. Therefore, the operator can detach the box **21** from the box holding mechanism **40**. The operator can extract a molded object from the detached box **21** or load the box **21** where a molded object is accommodated into a powder removing apparatus **300** that will be described below. Thus, operation efficiency can be increased.

Further, the clamping mechanism **56** according to the embodiment uses an electromagnetic clamping force. According to the embodiment, the box **21** is detachable from the box holding mechanism **40**, and the stage **22** is movably provided in the main body **23** of the box **21**. Therefore, it is assumed that a manufacturing error (a size error or the like) between the box **21** and the stage **22** occurs. However, compared with a case where a mechanical clamping force generated when members engage with each other is used, the use of the electromagnetic clamping force as in the embodiment of the present disclosure makes it possible to absorb the manufacturing error and clamp the stage.

(Molding Processing of Molding Apparatus)

FIGS. **8**A to **8**D are views successively showing mainly the molding operation of the molding apparatus **100** and are schematic views as seen from the lateral surface of the molding apparatus **100**.

Before the molding apparatus **100** forms a molded object, the CT data of the object to be molded or three-dimensional data such as DICOM (Digital Imaging and Communication in Medicine) obtained according to the CT data is input to the controlling unit **60**.

FIGS. **8**A to **8**D show, as will be described later, a process of forming one layer (corresponding to a predetermined layer thickness) where the powder **4** is cured (combined) by the ejection of the ink from the print head **41**. The powder **4** and powder **4** to be cured (combined) are indicated by dotted hatching, and a cured layer is indicated by black paint.

As shown in FIG. **8**A, the powder **4** is supplied from the tank shooter **15** into the supplying box **11** to be stored therein. On the stage **22** of the molding part **20**, the cured layer and the powder layer to be cured are laminated. In this state, the process of forming the one cured layer is started. In FIG. **8**A, the positions of the roller **16** and the print head **41** are set as their standby positions.

First, as shown in FIG. **8**B, the powder **4** stuck on the supplying stage **12** of the supplying part **10** is pushed upward by the elevating mechanism **70** (see FIG. **2** or the like), such that the powder **4** slightly greater in amount than the one powder layer is supplied up to a position higher in level than a top surface **2***b* of the plate **2**. Further, in the molding part **20**, when the stage **22** is caused to fall by the elevating mechanism **50**, space having a thickness of the one powder layer is provided between the top surfaces of the cured layer and the powder layer to be cured and the top surface **2***b* of the plate **2**.

In FIG. **8**B, a thickness u of the one powder layer is typically in the range of about 0.1 mm to 0.2 mm, but it may exceed or be less than the range.

As shown in FIG. **8**C, when the roller **16** rotates counterclockwise and moves in the direction as indicated by a solid-white arrow, the powder **4** supplied from the supplying part **10** is conveyed. Here, the roller **16** rotates in the direction opposite to the direction in which the roller **16** is assumed to rotate with the friction between the roller **16** and the molding part **20** when the roller **16** rotates in the direction of the solid-white arrow in its rotatable state (where no torque is applied to the rotary shaft **17** of the roller **16**). While being conveyed with such rotation of the roller **16**, the powder **4** fills in the space provided at the top surfaces of the cured layer and the powder layer to be cured of the molding part **20**. As a result, uniform powder layer is formed.

As shown in FIG. **8**D, the roller **16** passes through the molding part **20** and discharges the excessive powder **4** from the discharging path member **31**. Then, in synchronization with the returning operation of the roller **16** to the standby position, the print head **41** ejects the ink so as to draw a colorized image while being caused to move by the driving operation of the print head moving mechanism **46**. In this case, the aqueous ink (colorized ink and transparent ink) permeates through the powder layer, and thus the powders **4** having the ink permeated therethrough are bonded together to form the cured layer (combined layer).

The print head **41** ejects the transparent ink including the binder as described above to cure (combine) the powders. That is, when the transparent ink is ejected onto the same region as the region where the colorized ink (CMY ink) is ejected, the cured layer of the colorized powders is formed.

Note that in the case of forming a non-colorized cured layer, it is only necessary for the print head **41** to selectively eject only the transparent ink onto the molding enabling region.

Note that the print head **41** may start moving and ejecting the ink after the roller **16** completes the conveyance of the powder **4** and returns to the standby position. However, because the time period of the returning operation of the roller **16** and the time period of the moving operation of the print head **41** overlap each other as described above, the processing time can be reduced.

When the print head **41** returns to the standby position, the process returns to the state shown in FIG. **8**A where a colorized cured object corresponding to one layer is formed. Through the repetitive operations described above, the molding apparatus **100** laminates the cured layers together to form the molded object.

It may also be possible to obtain a molded object having higher hardness in such a manner that the molded object is heated by a heating apparatus (not shown) other than the molding apparatus **100**.

After the molding processing of the molding apparatus **100**, the operator detaches the box **21** from the molding unit **30**. The detachment of the box **21** only needs to be performed in an order reverse to the order described in FIGS. **7**A to **7**E. The operator only needs to pull out the forks **153** of the conveying cart **150** holding the box **21** from the molding apparatus **100** and directly convey the conveying cart **150** to the powder removing apparatus **300** that will be described below.

The processing of the molding apparatus **100** described above is shown on the left side of FIG. **9** as a flowchart.

(Powder Removing Apparatus)

Next, the powder removing apparatus will be described.

(Powder Removing Apparatus According to First Embodiment)

FIG. **10** is a schematic cross-sectional view showing the powder removing apparatus according to a first embodiment.

The powder removing apparatus **300** has a box holding mechanism **340** detachably holding the box **21** and a stage moving mechanism **350** that elevates and moves the stage **22** of the box **21** held by the box holding mechanism **340**. In addition, the powder removing apparatus **300** has a powder removing processing mechanism **370** that removes non-bonding powder **4** existing around a molded object **4'**.

The powder removing apparatus **300** has a supporting housing **362** and a covering member **325** that forms a powder removing chamber (powder removing operating region) **320** on the supporting housing **362**. A partition plate **324** is provided on the supporting housing **362**. The powder removing chamber **320** is formed by the partition plate **324** and the covering member **325**.

The covering member **325** is mainly made of, for example, a transparent acrylic resin or the like. The front of the covering member **325** is formed into a door **326** capable of opening and closing in a vertical direction. The covering member **325** is subjected to anti-static processing to prevent its visibility from being degraded due to the attachment of static-charged powder.

The powder removing processing mechanism **370** has gas-blowing nozzles **328** arranged inside the powder removing chamber **320** and an exhausting apparatus **330** that collects and exhausts powder. The exhausting apparatus **330** has an exhausting hood **335** that is arranged inside the powder removing chamber **320** and includes an exhausting fan. In addition, the exhausting apparatus **330** has an exhausting pipe **336** connected to the exhausting hood **335**. The exhausting apparatus **330** serves as an attracting mechanism.

As shown in FIG. **10**, the plurality of nozzles **328** may be provided. As gas to be ejected from the nozzles **328**, air is typically used. However, an inert gas such as nitrogen may be used. Although not shown, the nozzles **328** are connected to a tank where the gas is accommodated via pumps, valves, and the like. At least the nozzles **328** serve as the powder removing processing mechanism **370**. The powder removing processing mechanism **370** may include the exhausting apparatus **330**.

Under the partition plate **324**, the box holding mechanism **340**, a powder collecting part **360** adjacent to the box holding mechanism **340**, and the stage moving mechanism **350** are arranged. The exit of the exhausting pipe **336** of the exhausting apparatus **330** is arranged below the partition plate **324**, and the powder exhausted from the exhausting pipe **336** is collected into the powder collecting part **360**.

In some region of the partition plate **324**, a plurality of holes **324***a* are formed. The powder accumulated on the partition plate **324** falls from the holes **324***a*, slides off a slanted plate **369** arranged below the partition plate **324**, and is collected into the powder collecting part **360**.

In the partition plate **324**, an opening **324***b* formed into a shape corresponding to the outer shape or the inner diameter of the box **21** is provided. In a state where the box **21** is supported by the box holding mechanism **340**, the upper area of the main body **23** of the box **21** is inserted into the opening **324***b* or comes in contact with the periphery of the opening **324***b*.

The powder collecting part **360** has a collecting container **361** that forms a collecting region, a stirring mechanism **363** provided inside the collecting container **361**, a sieving mechanism **365** that is provided under the stirring mechanism **363** and collects a foreign substance, and a foreign substance removing mechanism **367** that removes the foreign substance collected by the sieving mechanism **365**.

The stirring mechanism **363** has a rotating body with a plurality of blades, a motor that drives the rotating body, and the like. The sieving mechanism **365** has a filtering member vibrated by, for example, a driving part (not shown). The foreign substance removing mechanism **367** is connected to the sieving mechanism **365** and exhausts the foreign substance using, for example, an exhausting fan (not shown) or the like. Examples of the foreign substance include materials other than the powder and lumps of the powders generated when a molded object is cracked or broken.

Because the box holding mechanism **340** has substantially the same structure and function as the box holding mechanism **40** of the molding apparatus **100**, the description of the structure and the function of the box holding mechanism **340** will be omitted. Further, because the stage moving mechanism **350** substantially has the same structure and function as the elevating mechanism **50** of the molding apparatus **100**, the description of the structure and the function of the stage moving mechanism **350** will be omitted. However, the box holding mechanism **340** and the stage moving mechanism **350** may have structures different from those of the box holding mechanism **40** and the elevating mechanism **50** of the molding apparatus **100**.

The box **21** is the one that has been loaded into the molding apparatus **100**. As described above, the box **21** conveyed from the molding apparatus **100** by the conveying cart **150** is loaded into the powder removing apparatus **300**.

FIG. **11** is a block diagram showing the configuration of the controlling system of the powder removing apparatus **300**.

The controlling system has a main controller **90**, a stage moving mechanism controller **91**, a box holding mechanism controller **92**, a gas ejection controller **93**, an exhausting fan controller **94**, an exhausting fan controller **95**, a sieving mechanism controller **96**, and a communicating part **97**.

The main controller **90** collectively controls the respective controllers **91** to **96** and the communicating part **97**. The stage moving mechanism controller **91** controls the driving operation of the stage moving mechanism **350**. The box holding mechanism controller **92** controls the driving operation of the box holding mechanism **340**. The gas ejection controller **93** controls the ON/OFF switching operation of the gas ejected from the nozzles **328** or the flow rate of the gas. The exhausting fan controllers **94** and **95** control, for example, the number of rotations of the respective fans to control their exhausting amounts. The sieving mechanism controller **96** controls at least one of the amplitude of a sieve and the frequency of the sieve.

The communicating part **97** is communicably connected to the controlling unit **60** of the molding apparatus **100** in a wired or wireless manner.

The main controller **90** is implemented by hardware elements used in a computer, such as a CPU, a RAM, and a ROM, and software. Alternatively, the controlling unit **60** may be implemented by a PLD (Programmable Logic Device) such as an FPGA (Field Programmable Gate Array), a device such as an ASIC (Application Specific Integrated Circuit), or the like.

Further, the respective controllers other than the main controller **90** and the communicating part **97** are composed of hardware or both hardware and software.

Next, the operations of the powder removing apparatus **300** thus configured will be described. FIG. **12** is a view for explaining part of the operations of the powder removing apparatus **300**.

The operator loads the conveying cart **150** holding the box **21** where molded objects are accommodated into the box holding mechanism **340** of the powder removing apparatus **300**. Because the operator loads the conveying cart **150** in the same manner as that when the operator loads the box **21** into the molding apparatus **100**, the description of the method of loading the conveying cart **150** will be omitted.

Prior to powder removing processing, the main controller **90** of the powder removing apparatus **300** acquires related information related to the molded objects accommodated inside the loaded box **21** from the controlling unit **60** of the molding apparatus **100**. In this case, the main controller **90** serves as an "acquiring part."

The related information includes three-dimensional data on the objects to be molded, the number of molded objects arranged inside the box **21**, and information on the number of shelves of the molded objects in a vertical direction. The related information may include information on the powder, the type of the ink, or the like. The operator only needs to perform an operation for acquiring the related information via an operations part (not shown) of the powder removing apparatus **300**.

As shown in FIG. **12**, the elevating arm **352** of the stage moving mechanism **350** moves upward by a predetermined height according to the control of the stage moving mechanism controller **91**. Here, the predetermined height substantially refers to, when the plurality of molded objects **4'** are arranged on the plurality of shelves in the vertical direction, the height of the one molded object **4'**. As described above, the main controller **90** acquires the related information from the controlling unit **60**. Therefore, the main controller **90** can recognize the height of the one molded object **4'**. In this case, the main controller **90** mainly serves as a "controlling part."

In FIG. **12**, the plurality of shelves are divided by dashed lines to show the height of the molded object **4'** on each of the shelves. With the upward movement of the stage **22** by the elevating arm **352** as described above, the molded object **4'** on the uppermost shelf is extruded from the box **21** via the opening **23***a* (see FIGS. **4**A and **4**B) of the main body **23**.

Then, the exhausting apparatus **330** starts operating according to the control of the exhausting fan controller **94**. The gas is ejected from the nozzles **328** at a predetermined flow rate according to the control of the gas ejection controller **93**, and mainly the non-bonding (non-curing) powder **4** existing around the molded object **4'** is scattered so as to get away from the molded object **4'**. That is, the non-bonding powder **4** is removed from the molded object **4'**. After that, the powder **4** is transferred to the powder collecting part **360** via the exhausting apparatus **330**. With the use of the nozzles **328** that eject the gas as described above, powder removing precision is increased.

When the powder removing processing with respect to the molded object **4'** on the uppermost shelf of the box **21** is completed, the operator or a robot opens the door **326** and extracts the molded object **4'** from the uppermost shelf. During the extraction of the molded object **4'**, the exhausting fan controller **94** may temporarily stop operating the exhausting apparatus **330** or continue to operate the exhausting apparatus **330** without interruption.

After the extraction of the molded object **4'** from the uppermost shelf by the operator or the robot, the door **326** of the powder removing chamber **320** is closed, and the elevating arm **352** of the stage moving mechanism **350** moves upward by the predetermined height. Then, similar to the case of the molded object **4'** on the uppermost shelf, the powder existing around the molded object **4'** accommodated on the second shelf of the box **21** is removed.

The powder removing apparatus **300** repeatedly performs the operations described above a number of times corresponding to the number of shelves of the molded objects **4'** accommodated inside the box **21**.

After the extraction of the molded object **4'** from the lowermost shelf of the box **21** by the operator or the robot, the box **21** is detached from the powder removing apparatus **300**. Because the operator detaches the box **21** from the powder removing apparatus **300** in the same manner as that when the operator detaches the box **21** from the molding apparatus **100**, the description of the method of detaching the box **21** from the powder removing apparatus **300** will be omitted.

The operator extracts the empty box **21** from the conveying cart **150** holding the empty box **21** or conveys the conveying cart **150** holding the empty box **21** to a predetermined position.

The processing of the powder removing apparatus **300** described above is shown on the right side of FIG. **9** as a flowchart.

As described above, according to the embodiment, the powder removing apparatus **300** removes the non-bonding powder **4** from the individual box **21** where the molded objects **4'** formed by the molding apparatus **100** are accommodated. Therefore, it is possible to prevent the inside of the molding apparatus **100** from becoming soiled by the powder **4**. That is, in a general powder-based rapid prototyping apparatus that does not use the detachable box **21** as in the embodiment of the present disclosure, a molding part (a head, a moving mechanism that moves the head, or the like) for a molded object becomes soiled by non-bonding powder because powder is scattered when an operator extracts the molded object buried in the powder from a box. However, the embodiment of the present disclosure can solve such a problem.

According to the embodiment, the stage moving mechanism **350** moves upward the stage **22** provided inside the box **21** to extrude the molded object **4'** from the box **21** via the opening **23***a* of the main body **23**. Thus, the new powder removing apparatus **300** capable of removing the non-bonding powder **4** from the upper part of the box **21** can be provided.

On the other hand, in a molding apparatus according to a reference example for comparison with the embodiment of the present disclosure, non-bonding powder is discharged from below a box so that it falls due to its own weight. In the case of such an apparatus, it is necessary for an operator to extract a molded object from the box and manually perform a powder removing operation, which takes much time and trouble.

Further, in a molding apparatus (molding apparatus according to a reference example for comparison with the embodiment of the present disclosure) where a plurality of molded objects are formed inside a box and powder is discharged at one time, the order and the arrangement of the plurality of molded objects are random. Under such a circumstance, for example, if the plurality of molded objects are similar in shape but are slightly different from each other, it may be impossible for an operator to discriminate the molded objects one from another.

Further, when the powder is discharged at one time from the molding apparatus, the molded objects rotate and collide against each other. Therefore, there is a likelihood of the molded objects being damaged (broken, cracked, and deformed).

According to the embodiment of the present disclosure, the plurality of molded objects **4'** accommodated on the plurality of shelves are extruded one by one from the main body **23**, and the powder is removed from the upper part of the box **21**. Therefore, compared with, for example, the case where the powder existing inside the box is removed at one time, it is possible to individually discriminate the plurality of molded objects **4'** from one another and successively extract them from above. Accordingly, the problems in the molding apparatuses according to the reference examples described above can be totally solved.

According to the embodiment, the sieving mechanism **365** and the foreign substance removing mechanism **367** remove a foreign substance from the powder. Therefore, it is possible to collect the non-bonding powder from which the foreign substance is removed and recycle the powder.

According to the embodiment, with the preparation of the plurality of boxes **21**, it is possible to perform the molding processing on the molded objects inside one of the plurality of boxes **21** with the molding apparatus **100** while performing the powder removing processing on the molded objects inside another of the boxes **21** with the powder removing apparatus **300**. Unlike an apparatus where a molding processing part and a powder removing processing part are, for example, integrally provided, such a molding system can reduce time during which the molding processing is suspended and increase productivity for the molded objects. As a result, the cost of the molding processing can also be reduced.

Further, the molding apparatus **100** and the powder removing apparatus **300** are separate apparatuses. Therefore, the maintenance of the respective apparatuses can be separately performed.

(Powder Removing Apparatus According to Second Embodiment)

FIG. **13** is a diagram showing the schematic configuration of a powder removing apparatus according to a second embodiment and the block configuration of the controlling system thereof. In the following description, the same members, functions, blocks, and the like as the powder removing apparatus **300** according to the first embodiment shown in FIGS. **10** and **11** will be simplified or omitted, and mainly different points will be focused.

The powder removing apparatus **400** according to the embodiment has nozzle driving mechanisms **376** that drive the respective nozzles **328**. The nozzle driving mechanisms **376** have, for example, respective translational movement mechanisms **372** and angle adjusting mechanisms **374**.

The translational movement mechanisms **372** translationally move the respective nozzles **328** along the one-dimensional (for example, an X axis) direction in FIG. **10**. As the translational movement mechanisms **372**, ball screw mechanisms or the like are used. The translational movement mechanisms **372** individually drive the respective nozzles **328**.

In order to change the ejecting directions of the nozzles **328**, the angle adjusting mechanisms **374** are connected to the nozzles **328** in a manner capable of adjusting the angles (postures) of the nozzles **328**. The angle adjusting mechanisms **374** may be manually adjusted by an operator. Alternatively, the angle adjusting mechanisms **374** may include respective motors, gears, and the like and be capable of (automatically) adjusting the angles of the nozzles **328** according to electric control. In the following description, the embodiment will be given using the angle adjusting mechanisms **374** as the mechanisms that adjust the angles of the nozzles **328** according to the electric control.

The gas ejection controller **93** controls the driving operations of the nozzle driving mechanisms **376**.

Note that in FIG. **13**, the translational movement mechanisms **372** are individually provided for the nozzles **328**. However, one nozzle driving mechanism may be provided and collectively drive the plurality of nozzles **328**. Alternatively, a mechanism may be provided that translationally moves the nozzles not only in the one-dimensional direction along the X axis but also in a two-dimensional direction including the Y axis or the Z axis or in a three-dimensional direction including both the X axis and the Y axis or the Z axis. In this case, it is only necessary for the moving mechanism to have moving axes corresponding to the number of arbitrary dimensions according to the mode (the shape, the arrangement, and the number, or the like) of the nozzles **328**. For example, if a plurality of nozzles are arranged along the X axis direction, a mechanism that translationally moves the nozzles along the X axis direction does not need to be provided. Alternatively, one ejection head having a plurality of nozzles (or the plurality of ejection heads) may be provided inside the powder removing chamber **320**.

Further, the powder removing apparatus **400** has a weight sensor **368** that detects the weight of the collecting container **361**. The weight sensor **368** detects the weight of the non-bonding powder **4** collected into the collecting container **361** having a predetermined weight. The main controller **90** is capable of acquiring information detected by the weight sensor **368**.

At the powder removing processing, the powder removing apparatus **400** thus configured extrudes molded objects on shelves one by one from the box **21** and removes non-bonding powder as in the first embodiment. At this time, the gas ejection controller **93** controls the nozzle driving mechanisms **376** according to related information, particularly three-dimensional data, on the molded objects acquired from the controlling unit **60** via the main controller **90**. The nozzle driving mechanisms **376** perform at least one of the translational movements of the nozzles **328** and the adjustment of the angles of the nozzles **328** according to the shapes of the molded objects. With such driving control, the gas is ejected from positions most suitable for the powder removing processing

Moreover, the gas ejection controller **93** can control the ejection of the gas so that it takes longer time or the gas is ejected at a greater flow rate for performing the powder removing processing on molded objects having complicated shapes (the molded objects having first surface areas), compared with a case where the powder removing processing is performed on molded objects having uncomplicated shapes (molded objects having second front surface areas smaller than the first front surface areas). As described above, because the three-dimensional data used for forming the molded objects is used, it is not necessary for the main controller **90** to generate separate information. In addition, because the powder removing processing is finely performed according to the three-dimensional data, powder removing precision is increased.

According to the embodiment, the main controller **90** determines progress on the powder removing processing of the powder removing processing mechanism **370** according to the information detected by the weight sensor **368**. In this case, the main controller **90** and the weight sensor **368** serve as a "determining part."

For example, if the value detected by the weight sensor **368** is less than or equal to a threshold, the main controller **90** continues to perform the powder removing processing. On the other hand, if the value exceeds the threshold, the main controller **90** stops the powder removing processing. The stop of the powder removing processing refers to, for example, stopping the operation of the exhausting apparatus **330**, stopping the ejection of the gas from the nozzles, or the like. The threshold refers to a value set based on, for example, the volume of the box **21**, the volumes of the molded objects **4'**, or the like. Further, the volumes of the molded objects **4'** can be calculated based on the three-dimensional data acquired by the controller **90** from the controlling unit **60**.

As described above, the main controller **90** can recognize the progress on the powder removing processing based on the measured amount of the non-bonding powder.

(Third Embodiment)

Although not shown, a powder removing apparatus according to a third embodiment has a sensor that detects the degree of clearness of air inside the powder removing chamber **320**. As the sensor, an optical sensor is, for example, used.

The optical sensor may be a transmission type or a reflection type that detects scattered light. The sensor may be an image sensor. During the powder removing processing, the degree of clearness of the air inside the powder removing chamber **320** is low because the powder rises into the powder removing chamber **320**. However, if a predetermined degree of clearness of the air is obtained, it can be used as a trigger for completing the powder removing processing. The main controller **90** can recognize progress on the powder removing processing based on the information detected by the sensor.

(Other Embodiments)

The present disclosure is not limited to the embodiments described above and can achieve various other embodiments.

According to the embodiments described above, the boxes **21** are detachably provided. However, the boxes **21** may be fixed to the molding apparatus and the powder removing apparatus. For example, it may be possible that the plurality of boxes **21** are provided in the powder removing apparatus (or the molding apparatus) and that the powder removing apparatus has a mechanism where the plurality of boxes **21** collectively move in a horizontal plane. The mechanism where the plurality of boxes **21** collectively move in the horizontal plane may be, for example, a rotating mechanism where the boxes **21** rotate (revolve) about a point. At least one of the boxes **21** arranged at a predetermined position is to be subjected to the powder removing processing according to the powder removing processing method described above (subjected to the molding processing according to the molding processing method described above).

If the molding apparatus or the powder removing apparatus has the mechanism where the plurality of boxes **21** collectively move in the horizontal plane, the boxes **21** may be, of course, detachably provided in the apparatus.

Each of the powder removing apparatuses described above may have, instead of or in addition to the nozzles **328** that eject the gas, a device such as a brush that comes in physical contact with the molded objects **4** and removes the non-bonding powder **4'** existing around the molded objects **4**.

In each of the powder removing apparatuses described above, the main controller can also control the upward-movement speed of the stage **22**, the method of moving the stage **22** upward, the number of nozzles **328** for use in the powder removing processing, or the like.

As the mechanisms of the main parts in the box holding mechanisms **40** and **340** described above, the fluid pressure cylinders are used. However, instead of the fluid pressure cylinders, ball screw mechanisms, rack-and-pinion mechanisms, belt mechanisms, or the like may be used.

In the powder removing apparatus according to the second embodiment, the weight sensor is provided as the device that measures the amount of the powder. However, the device is not limited to the weight sensor. For example, an image sensor or an optical sensor may detect how deep the powder **4** is accumulated inside the collecting container, and the main controller may calculate the amount (weight or volume) of the powder based on the detected information.

Each of the powder removing apparatuses described above may have identifiers for identifying the boxes **21** in each of the boxes **21**, instead of or in addition to the method of acquiring the three-dimensional shape data from the molding apparatus **100**. Examples of the identifiers include IC tags and information codes (such as barcodes and two-dimensional information codes). As a result, each of the powder removing apparatuses can control the powder removing processing for each of the boxes **21** or for each of the molded objects accommodated inside the boxes **21**.

In the above description related to each of the powder removing apparatuses, the plurality of molded objects are accommodated inside the box **21**. However, even if one molded object **4'** is accommodated inside the box **21**, non-bonding powder **4** existing around the molded object **4'** only needs to be removed by the continuous or intermittent ejection of the gas from the nozzles **328** while the elevating arm **352** moves the stage **22** upward in stages (intermittently). Alternatively, the non-bonding powder **4** may be removed while the elevating arm **52** continuously moves the stage **22** upward. Even if the stage **22** is continuously moved upward like this, the powder removing apparatus **300** can variably control the upward movement speed of the stage **22** according to three-dimensional shape data as described above.

As the clamping mechanism **56** according the embodiment described above, an electromagnetic clamp is used. However, as the clamping mechanism, a mechanism that generates a clamping force with capacitance or a mechanism that generates a clamping force with mechanical engagement may be used.

As the elevating members of the elevating mechanisms **50** and **70**, the L-shaped elevating arms are exemplified in the embodiments described above. However, the elevating members are not limited to such an L-shape and may be formed into any shape such as a rod shape. The same applies to the stage moving mechanism **350**.

The shape of the box is not limited to the square cylinder as in the embodiment described above and may be a triangle cylinder, a cylinder of pentagon or more, a cylinder, an elliptic cylinder, a combination of at least two of these cylinders, or any other shapes.

According to the embodiment described above, the molding apparatus **100** and the powder removing apparatus **300** are separately provided. However, they may be integrally provided.

Alternatively, the present disclosure is also applicable to a molding system where the molding apparatus **100** and the powder removing apparatus **300** are arranged inline regardless of whether they are integrally provided or separately provided and an automatic conveying apparatus conveys the box **21** between the molding apparatus **100** and the powder removing apparatus **300**. As the automatic conveying apparatus, an AGV (Automatic Guided Vehicle) such as an RGV (Rail Guided Vehicle) and a PGV (Personal Guided Vehicle) is, for example, used.

As the automatic conveying apparatus, a conveying apparatus having no wheels such as an arm-and-hand may be, for example, used. In this case, the molding apparatus **100** and the powder removing apparatus **300** may be configured as an integrated apparatus together with such a conveying apparatus having no wheels.

It may also be possible to prepare boxes having different volumes according to at least the sizes of molded objects among three-dimensional shape data on the molded objects. For example, in the case of forming a small molded object, the controlling unit **60** of the molding apparatus **100** selects a small box corresponding to the small molded object and performs the molding processing using the small box. Thus, the use amount of the powder can be saved compared with a case where boxes having the same volume are used. In this case, the outer shapes of the boxes and the sizes thereof may be substantially the same among the boxes, and the boxes only need to be formed so as to have different volumes.

As the powder, metal and a resin may be used besides the materials described above. In the case of using metal powder, the metal powder can be bonded (cured) by sintering. In order to selectively sinter the metal powder existing in the molding enabling region, laser light is used.

Further, in a case where metal powder having magnetic properties is used and an electromagnetic clamp as in the embodiment described above is used as the clamping mechanism **56**, a magnetic shield that interrupts the magnetic field between the upper surface and the lower (rear) surface of the stage **22** only needs to be provided.

The elevating mechanism **50** elevates and moves the stage **22** relative to the main body **23**. However, the elevating mechanism **50** may elevate and move the main body **23** relative to the stage **22**. The stage moving mechanism **350** of the powder removing apparatus **300** also elevates and moves the stage **22** relative to the main body **23**. However, the stage moving mechanism **350** may elevate and move the main body **23** relative to the stage **22**. In this case, the stage moving mechanism **350** may gradually move the main body **23** downward in a state where the lower end of the box **21** is positioned at a height near the partition plate **324**.

According to the embodiment described above, the controlling unit **60** of the molding apparatus **100** and the communicating part **97** of the powder removing apparatus **300** are communicably connected to each other. However, a computer as a server may be communicably connected to the molding apparatus **100** and the powder removing apparatus **300** and manage the same.

Among the features of the respective embodiments described above, at least two of them may be combined together.

Note that the present disclosure may also employ the following configurations.

(1) A powder removing apparatus, including:

a box having a main body with an opening and a stage movably provided in the main body,

the box being capable of accommodating a molded object and non-bonding powder so as to arrange the molded object, which is formed using powder according to a rapid prototyping technique, on the stage together with the non-bonding powder;

a stage moving mechanism capable of moving the stage upward relative to the main body inside the main body; and

a powder removing processing mechanism configured to remove the non-bonding powder existing around the molded object extruded by a driving operation of the stage moving mechanism via the opening.

(2) The powder removing apparatus according to (1), in which

the box is capable of vertically accommodating a plurality of molded objects on a plurality of shelves, and

the powder removing apparatus further includes

a controlling part configured to

operate the stage moving mechanism such that corresponding one of the plurality of molded objects accommodated on the plurality of shelves is extruded from the main body for each of the plurality of shelves, and

operate the powder removing processing mechanism for each of the plurality of shelves.

(3) The powder removing apparatus according to (1), further including:

an acquiring part configured to acquire related information related to the molded object inside the main body of the box; and

a controlling part configured to operate the powder removing processing mechanism based on the acquired related information.

(4) The powder removing apparatus according to (3), in which

the acquiring part is configured to acquire at least three-dimensional data on the object to be molded for use in the rapid prototyping technique as the related information.

(5) The powder removing apparatus according to (4), in which

the powder removing processing mechanism includes

a nozzle configured to eject gas onto the molded object, and

a nozzle driving mechanism configured to variably drive at least one of a position and a posture of the nozzle according to control of the controlling part based on the three-dimensional data.

(6) The powder removing apparatus according to any one of (1) to (5), in which

the powder removing processing mechanism includes

a powder removing operating region,

a nozzle configured to eject gas onto the molded object, and

an attracting mechanism configured to attract the non-bonding powder existing in the powder removing operating region.

(7) The powder removing apparatus according to (1), further including:

a determining part configured to determine progress on powder removing processing of the powder removing processing mechanism.

(8) The powder removing apparatus according to (7), in which

the determining part includes a sensor configured to detect an amount of the non-bonding powder collected from the powder removing processing mechanism.

(9) The powder removing apparatus according to (7), in which

the determining part includes a sensor configured to detect a degree of clearness of air inside a powder removing operating region of the powder removing processing mechanism.

(10) The powder removing apparatus according to any one of (1) to (9), further including:

a sieving mechanism configured to remove a foreign substance from the non-bonding powder collected from the powder removing processing mechanism.

(11) The powder removing apparatus according to any one of (1) to (10), further including:

a supporting mechanism configured to detachably support the box.

(12) A molding system, including:

a molding apparatus configured to form a molded object using powder according to a rapid prototyping technique; and

a powder removing apparatus including

a box having a main body with an opening and a stage movably provided in the main body,

the box being capable of accommodating the molded object and non-bonding powder so as to arrange the molded object formed by the molding apparatus on the stage together with the non-bonding powder,

a stage moving mechanism capable of moving the stage upward relative to the main body inside the main body, and

a powder removing processing mechanism configured to remove the non-bonding powder existing around the molded object extruded by a driving operation of the stage moving mechanism via the opening.

(13) A method of manufacturing a molded object, including:

forming the molded object using powder according to a rapid prototyping technique;

moving a stage upward relative to a box inside a main body of the box,

the box having the main body with an opening and the stage movably provided in the main body,

the box being capable of accommodating the molded object and non-bonding powder so as to arrange the molded object on the stage together with the non-bonding powder; and

removing the non-bonding powder existing around the molded object extruded by the upward movement of the stage via the opening of the box.

The present disclosure contains subject matter related to that disclosed in Japanese Priority Patent Application JP 2011-186676 filed in the Japan Patent Office on Aug. 30, 2011, the entire content of which is hereby incorporated by reference.

It should be understood by those skilled in the art that various modifications, combinations, sub-combinations and alterations may occur depending on design requirements and other factors insofar as they are within the scope of the appended claims or the equivalents thereof.

What is claimed is:

1. An apparatus, comprising:

a chamber with a floor, the floor having an opening;

a box having a main body with an opening and a stage movable within the main body, the box being capable of accommodating therein a formed object and non-bonded powder on the stage within the box;

a box holding mechanism to hold the box in registration with the opening in the floor of the chamber;

a stage moving mechanism capable of controllably moving the stage vertically inside the main body and relative to the main body to expose the formed object and the non-bonded powder to the chamber;

a powder removing processing mechanism configured to remove the non-bonded powder existing around the formed object by moving the stage relative to the box opening while applying a gas to the formed object and the non-bonded powder, the powder removing processing mechanism including an exhaust fan system to remove powder entrained in the gas and holes in the floor via which the non-bonded powder can fall through;

a container positioned to catch the non-bonded powder falling through the holes in the floor; and

a nozzle driving mechanism configured to control ejection of the gas onto the formed object according to a weight of the non-bonded powder collected into the container, wherein the exhaust fan system is structured to direct exhaust gas to the container.

2. The apparatus according to claim 1, wherein

the box is capable of vertically accommodating a plurality of formed objects on a plurality of shelves, and

the apparatus further comprises a controlling part configured to (a) operate the stage moving mechanism such that corresponding one of the plurality of formed objects accommodated on the plurality of shelves is extruded from the main body for each of the plurality of shelves, and (b) operate the powder removing processing mechanism for each of the plurality of shelves.

3. The apparatus according to claim 1, further comprising:

an acquiring part configured to acquire related information related to the formed object inside the main body of the box; and

a controlling part configured to operate the powder removing processing mechanism based on the acquired related information.

4. The apparatus according to claim 3, wherein the acquiring part is configured to acquire at least three-dimensional data related to the formed object.

5. The apparatus according to claim 4, wherein the powder removing processing mechanism includes:

an articulating nozzle configured to eject the gas onto the formed object, and

the nozzle driving mechanism configured to variably drive at least one of a position and a posture of the nozzle according to control of the controlling part based on the three-dimensional data.

6. The apparatus according to claim 1,

wherein the powder removing processing mechanism includes, a nozzle configured to eject the gas onto the formed object.

7. The apparatus according to claim 1, further comprising: a determining part configured to determine progress of powder removing processing of the powder removing processing mechanism.

8. The apparatus according to claim 7,

wherein the determining part includes a sensor configured to detect an amount of the non-bonded powder collected from the powder removing processing mechanism.

9. The apparatus according to claim 7, wherein the determining part includes a sensor configured to detect a degree of clearness of atmosphere inside the chamber.

10. The apparatus according to claim 1, further comprising: a sieving mechanism configured to remove a foreign substance from the non-bonded powder entering the container.

11. The apparatus according to claim 1, wherein the box holding mechanism is configured to move the box vertically relative to the opening in the floor of the chamber.

12. A molding system, comprising:

a molding apparatus configured to form a formed object using powder according to a rapid prototyping technique; and

an apparatus comprising:

a chamber with a floor, the floor having an opening;

a box having a main body with an opening and a stage movable within the main body, the box being capable of accommodating therein a formed object and non-bonded powder on the stage within the box;

a box holding mechanism to hold the box in registration with the opening in the floor of the chamber;

a stage moving mechanism capable of controllably moving the stage vertically inside the main body and relative to the main body and to expose the formed object and the non-bonded powder to the chamber;

a powder removing processing mechanism configured to remove the non-bonded powder existing around the formed object by moving the stage relative to the box opening while applying a gas to the formed object and the non-bonded powder, the powder removing processing mechanism including an exhaust fan system to remove powder entrained in the gas and holes in the floor via which the non-bonded powder can fall through;

a container positioned to catch the non-bonded powder falling through the holes in the floor; and

a nozzle driving mechanism configured to control ejection of the gas onto the formed object according to a weight of the non-bonded powder collected into the container,

wherein the exhaust fan system is structured to direct exhaust gas to the container.

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